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SUBSTITUTE CHEMICAL PROGRAM

INITIAL SCIENTIFIC AND MINIECONOMIC REVIEW OF BROMACIL

MIDWEST RESEARCH INSTITUTE

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

MARCH 1975

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16. Abstracts: This is the 4th in a series of in-depth scientific literature searches which review the safety and efficacy of substitute chemicals registered by EPA as possible replacements for cancelled or suspended pesticides or pesticides in litigation. The reviews are part of the Substitute Chemical Program, initiated under PL 93-135 (October 1973). This report on bromacil, a registered substitute chemical for certain cancelled and suspended uses of 2,4,5-T , covers all uses of bromacil and is intended to be adaptable to future needs. It also, where applicable, identifies areas where technical data may be lacking so that appropriate studies may be initiated to develop desirable information.The data contained in this report was not intended to be complete in all areas. The review is a compilation and summarization of published and unpublished scientific test and use data from various sources, including: journals, books, Federal and State agency reports, and manufacturer and university reports.

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pharmacology	toxicity	
toxicology	physiological effects	
fate in the environment	limitations in data	
production of bromacil	efficacy and cost effectiveness	
registered uses		
economic review		

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U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDE PROGRAMS
CRITERIA AND EVALUATION DIVISION
WASHINGTON, D.C. 20460

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This report has been compiled by the Criteria and Evaluation Division, Office of Pesticide Programs, EPA in conjunction with other sources listed in the Preface. Contents do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

PREFACE

The Alternative (Substitute) Chemicals Program was initiated under Public Law 93-135 of October 24, 1973, to "provide research and testing of substitute chemicals." The legislative intent is to prevent using substitutes, which in essence are more deleterious to man and his environment, than a problem pesticide (one that has been suspended, cancelled, deregistered or in an "internal review" for suspected "unreasonable adverse effects to man or his environment"). The major objective of the program is to determine the suitability of substitute chemicals which now or in the future may act as replacements for those uses (major and minor) of pesticides that have been cancelled, suspended, or are in litigation or under internal review for potential unreasonable adverse effects on man and his environment.

The substitute chemical is reviewed for suitability considering all applicable scientific factors such as: chemistry, toxicology, pharmacology and environmental fate and movement; and socio-economic factors such as: use patterns and costs and benefits. EPA recognizes the fact that even though a compound is registered it still may not be a practical substitute for a particular use or uses of a problem pesticide. The utilitarian value of the "substitute" must be evaluated by reviewing its biological and economic data. The reviews of substitute chemicals are carried out in two phases. Phase I conducts these reviews based on data bases readily accessible at the present time. An Initial Scientific Review and Minieconomic Review are conducted simultaneously to determine if there is enough data to make a judgment with respect to the "safety and efficacy" of the substitute chemical. Phase II is only performed if the Phase I reviews identify certain questions of safety or lack of benefits. The Phase II reviews conduct in-depth studies of these questions of safety and cost/benefits and consider both present and projected future uses of the substitute chemicals.

The report summarizes rather than interprets scientific data reviewed during the course of the studies. Data is not correlated from different sources. Opinions are not given on contradictory findings.

This report contains the Phase I Initial Scientific and Minieconomic Review of Bromacil (5-bromo-3-sec-butyl-6-methyluracil). Bromacil was identified as a registered substitute chemical for certain cancelled and suspended uses of 2,4,5-T. Where applicable, the review also identifies areas where technical data may be lacking so that appropriate studies may be initiated to develop desirable information.

The review covers all uses of bromacil and is intended to be adaptable to future needs. Should bromacil be identified as a substitute for a problem pesticide other than 2,4,5-T, the review can be updated and made readily available for use. The data contained in this report was not intended to be

complete in all areas. Data-searches ended in December, 1974. The review was coordinated by a team of EPA scientists in the Criteria and Evaluation Division of the Office of Pesticide Programs. The responsibility of the team leader was to provide guidance and direction and technically review information retrieved during the course of the study. The following EPA scientists were members of the review team: Fumihiko Hayashi, Ph.D. (Team Leader); Carroll Collier (Chemistry); William Burnam (Pharmacology and Toxicology); John Bowser (Fate and Significance in the Environment); John Leitzke (Fate and Significance in the Environment); Richard Petrie (Registered Uses); Jeff Conopask (Economics).

Data research, abstracting and collection were primarily performed by Midwest Research Institute, Kansas City, Missouri (EPA Contract #68-01-2448). RvR Consultants, Shawnee Mission, Kansas, under a subcontract to Midwest Research, assisted in data collection. E. I. du Pont de Nemours and Company, a manufacturer of bromacil, made certain comments and additions to this report.

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PART I. SUMMARY

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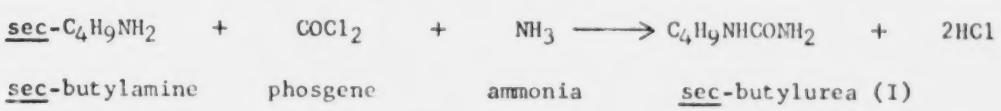
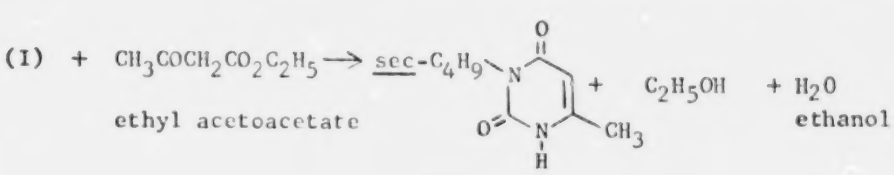
This section contains a brief summary of the "Initial Scientific and Minieconcmic Review" on bromacil. The section summarizes rather than intreprets data reviewed.

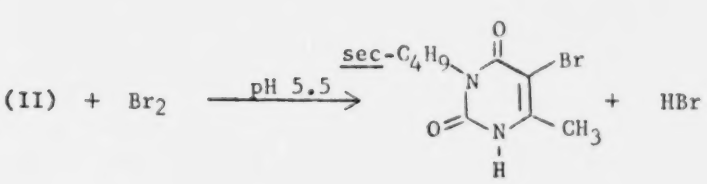
Production and Use

Bromacil (5-bromo-3-sec-butyl-6-methyluracil) is one of a family of substituted uracils used as herbicides. Three reactions are required for its manufacture:





3-sec-butyl-6-methyluracil (II)



Bromacil

The only domestic manufacturer of bromacil and other substituted uracils is E. I. du Pont de Nemours and Company, Inc. Their production facility, which is located in La Porte, Texas, has an estimated capacity of 20 million pounds per year of total uracils.

The chemistry of bromacil reported in available literature primarily concerns degradation reactions. Bromacil is reported to be slowly decomposed in strong acid, but is stable in water, aqueous base, common organic solvents, and at temperatures up to its melting point (158 to 159°C). Degradation by ultraviolet radiation has also been reported.

Bromacil is a broad-spectrum herbicide used for control of annual and perennial grasses and broadleaf weeds, for nonselective weed and brush control on noncropland, and for selective weed control on a limited number of crops. Bromacil is commercially available in formulation as a single active ingredient, and in combination with diuron, sodium metaborate, and sodium chlorate.

An estimated 3 million pounds of bromacil active ingredient (AI) were used domestically in 1972. Of that quantity, about 400,000 lb AI were used for agricultural purposes (primarily for weed control in citrus groves located in the Southwestern states, and in pineapple fields in Hawaii); 2,300,000 lb AI were used by industrial and commercial organizations; and about 300,000 lb AI by government agencies. Bromacil is not registered for home and garden use.

Estimated 1972 regional uses of bromacil are: South Central states--about 25%, Southwestern states--about 20%, Southeastern states--about 20%, North Central states--13%, and the Northeastern and Northwestern states--less than 10% each.

Toxicity and Physiological Effects

No data was found on effects of bromacil on humans, either on an acute basis or under field conditions or in the manufacturing processes. Bromacil, however, is not a highly toxic compound. The spectrum of its toxicity as evaluated in rats is as follows:

Acute oral toxicity - LD_{50} = 5,200 mg/kg.

Acute inhalation toxicity - No deaths occurred after 4 hr in a 4.8 mg/liter environment.

Subacute oral toxicity (10-day study) - No deaths occurred after 10 daily doses of 650 mg/kg, and five out of six animals survived 10 daily doses of 1,035 mg/kg. In contrast, four out of five animals died after five doses of 1,500 mg/kg. At both the 650 and 1,035 mg/kg doses, pathological changes were observed in the liver immediately after the final (10th) dose. No pathological changes were observed in the livers, after a 14-day recovery period.

Chronic oral toxicity (2-year study) - Female rats on the highest dose level tested (1,250 ppm) suffered weight retardation during first and second years. There were no clinical signs of toxicity. No unusual alterations were observed during hematological, urinalysis, and clinical chemistry evaluations. There were no gross pathological lesions. There appeared to be a dose-related effect on the thyroid. Slight hyperplasia of the thyroid was noted at the highest dose level.

An acute oral toxicity evaluation could not be obtained in dogs because of emesis. Five grams per kilogram, as a single dose or as divided doses, produced excessive emesis. Emesis was still observed at the 200 to 250 mg/kg level. Signs of toxicity in dogs were salivation, weakness, loss of coordination, excitability, diarrhea and nydriosis. In long term studies with rats, bromacil did not appear to accumulate in tissues.

In a 2-year chronic oral toxicity test, groups of dogs were maintained on 0.005, 0.025, and 0.125% bromacil in the diet. Only one death occurred, and that dog was on the 0.005% diet; the cause of death was not associated with the compound. A loss in weight was noted at the high dose at the beginning of the experiment.

Bromacil is moderately toxic to ruminants. Cattle suffered weight loss and were poisoned with a single dose at 250 mg/kg. Sheep were also poisoned and had a weight loss after three 250 mg/kg doses of bromacil were given by drench or capsule; a dose (drench) of 100 mg/kg also caused poisoning and weight loss. None of the ruminants died.

In in vitro tests, bromacil reduced the amount of dry matter digested by rumen bacteria. Bromacil did not effect volatile fatty acid production. A decrease in the number of ciliated protozoa in rumen fluid in the presence of bromacil was noted.

Chickens appear to tolerate a dose of 500 mg/kg. There was a significant reduction in weight gain at this level.

The effect of bromacil on the reproduction of rats was evaluated in a three-generation study. Addition of 0.025% bromacil to the diet did not markedly effect the reproductive performance; no deformed young were produced.

Very little information exists as to the site of bromacil metabolism, distribution or retention, the enzymes involved, and the cofactor requirements.

Bromacil is metabolized and excreted as six metabolites by rats, one being 5-bromo-3-sec-butyl-6-hydroxymethyluracil. In cases of human industrial exposure, bromacil and its primary metabolite, 5-bromo-3-sec-butyl-6-hydroxymethyluracil was detected in urine.

No gross manifestations of teratogenic effects were observed in the fetuses of pregnant rabbits consuming as much as 250 ppm from the eighth day of pregnancy to the 16th day.

There is no indication from the literature review that bromacil produces oncogenic effects.

Food Tolerances and Acceptable Intake

Bromacil has not been reported as a significant residue in any class of food, but is not necessarily detected by the analytical system routinely used to monitor pesticide residues in food.

Tolerances have been established for bromacil on only two crops in the United States, citrus fruits and pineapples. Both tolerances have been set at 0.1 ppm.

An acceptable daily intake (ADI) has not been established for bromacil. An ADI has not been considered by the Food and Agricultural Organization/World Health Organization (FAO/WHO).

Environmental Effects

Bromacil displayed a low order of toxicity to six fish species as well as tadpole, crawfish and waterflea. The eight-day dietary LC_{50} for both the mallard duck and the bobwhite quail was > 10,000 ppm. Bromacil was tested as a spray at 10,000 ppm against housefly, roach aphid (systemic) and mite and was found to be totally lacking in insecticidal or acaricidal activity.

Stains of Euglena, an aquatic algae, were not affected by 40 ppm bromacil, and were only partially inhibited by 100 ppm. One wild strain of Euglena, however, was markedly inhibited by 2 ppm and completely inhibited by 10 ppm (none of the strains were affected by bromacil in the dark).

A number of soil fungi have shown uninhibited growth with bromacil. Ten soil fungi (Aspergillus tamarii, A. niger, A. flavus, A. oryzae, Curvularia lunata, Mucor pusillus, Trichoderma viride, Penicillium funiculosum, P. brevicompactum, and Myrothecium verucaria) were cultured on liquid broth media with bromacil levels from 250 to 5,000 ppm for 5 days. Bromacil, up to 2,000 ppm did not inhibit the growth of the fungi; except A. niger, which was inhibited by bromacil levels less than 1,500 ppm.

No statistically significant differences were found in the ammonium and nitrate nitrogen contents of, nor in the amounts of carbon dioxide evolved from untreated sandy loam and that from loam treated with 4 ppm bromacil (twice the application rate recommended for this type of soil).

The available data indicates that certain soil microorganisms are capable of degrading bromacil, and that normal bromacil concentrations in the soil, i.e., those that might be expected from its use in accordance with label directions, do not appear to adversely affect the soil microflora.

Available data indicates that bromacil is not strongly adsorbed on soil colloids.

Bromacil residues in the soil appear to be quite persistent. In one test, the half-life of a 4 lb AI/acre application to the surface of a Butlertown silt loam was found to be about 5 to 6 months. At higher application rates, the herbicidal activity of bromacil seemed to persist for two or more seasons.

Other investigations involving the application of 1 and 4 lb of bromacil per acre to six California locations found bromacil to be persistent. One year after application (for both application rates) plots remained toxic to barley, milo, sugar beets, alfalfa, tomatoes, and wheat.

In vitro studies show that some microorganisms have the ability to metabolize bromacil. The solubility of bromacil in water could be resulting rainfall being a factor in soil persistence.

Regarding bromacil residues in air, one study showed that the rate of bromacil volatilization in an air circulation oven maintained at 120°F was less than 0.1%/week. Other studies indicated that bromacil is very stable to photodecomposition.

Limitations in Available Scientific Data

The review of scientific literature was based on available sources given limitations of time and resources. Data was not found in a number of pertinent areas.

1. The effect of bromacil on humans.
2. Intraperitoneal and intravenous LD_{50} values on at least one species.
3. Inhalation data on more species than the rat.
4. A long-term (2 years) study in rats at a dose level higher than 0.125%.
5. Data related to behavioral effects and the effects on tissue culture growth and viability.
6. Field data on effects on fish.
7. Field data on effects of wildlife.
8. Additional data on the effects on the soil microflora and on effects on soil microfauna.

9. Data from national or regional soil monitoring studies on pesticide residues.

10. Laboratory or field data on effects on lower aquatic organisms.

11. Additional information on the presence, fate, and persistence of bromacil residues in water, sediment, or other elements of the aquatic ecosystem.

12. Additional data on the presence, fate, or persistence of bromacil residues in air.

13. Data on the possible bioaccumulation or biomagnification of bromacil.

14. Specific data on the environmental transport mechanisms of bromacil.

Bromacil is used primarily as a nonselective industrial herbicide on noncropland, and limitations in environmental data should be evaluated in terms of this use pattern.

Efficacy and Cost Effectiveness

Bromacil is used as a broad-spectrum herbicide to control annual and perennial grasses and brush in pineapple and citrus orchards, along railroads and highway right-of-ways, around utility poles, and along drainage ditches, canals and fences.

Bromacil has effectively controlled Bermuda grass, Vasey grass, nutsedge, crabgrass, Bahia grass and sweetgrass. It also controls willow, cottonwood, water locust, post oak, blackjack oak, hickory, maple, wild cherry, sweet gum, elm and a wide variety of other brush.

The economic benefit from using bromacil on oranges was determined from one experiment in Florida. At a rate of 3.5 lb/acre, the economic benefit amounted to $27.25/acre from the increased yield of oranges (based on 1972 cost data). No other economic benefit data was found.

Economic benefits from noncrop applications (e.g., grass and brush control along highways, utility lines, and railroads) are best measured by an alternative costing method. Alternative methods to chemical control include mechanical control such as mowing, discing, bulldozing and the use of brush cutting machines. Hand labor is often required for mowing around trees, poles and other objects and for weeding or cutting brush. In some cases burning for control of grasses along canal banks is an alternative.

The true economic benefits cannot be measured because much of the noncrop weed control is for aesthetic reasons such as beautification of highways. It is also a form of preventative maintenance to keep fires from causing damage when grasses are dry. Therefore, the cost of the chemical control should be subtracted from the alternative control cost, such as hand labor or mechanical control, to determine the economic benefit from the use of bromacil.

Selected tests comparing the use of chemical treatment to alternative methods such as mechanical or hand labor control for noncrop weed and brush removal showed economic benefits ranging from a decreased cost of $6.50/acre for chemical control of weeds and brush along irrigation ditches in California, to a $175.00/acre cost reduction for treatment of flood control dikes in West Springfield, Massachusetts. However, a more accurate assessment of economic benefits would require cost data over at least a 3-year period because initial costs of chemical treatment are much higher than subsequent chemical treatment costs.

PART II. INITIAL SCIENTIFIC REVIEW

SUBPART A. CHEMISTRY

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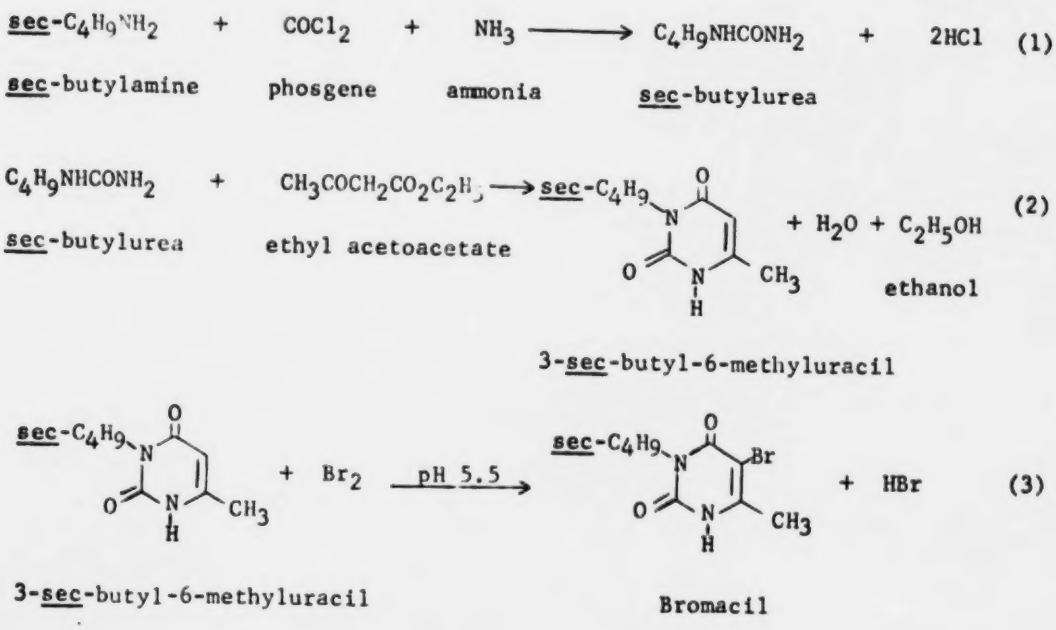
This section reviews available data on bromacil's chemistry and presence in foods. Eight subject areas have been examined: Synthesis and Production Technology; Physical Properties of Bromacil; Composition and Formulation; Chemical Properties, Degradation and Decomposition Processes; Occurrence and Residues in Food and Feed Commodities; Acceptable Daily Intake; and Tolerances. The section summarizes rather than interprets scientific data reviewed.

Synthesis and Production Technology

Bromacil is one of a family of substituted uracils used as herbicides. The production steps are similar for all members of the family, the differences being primarily in the starting materials. The chemical synthesis of bromacil is as follows (von Rumker et al., 1974)[1/]:



1/ von Rümker, R., E. W. Lawless, and A. F. Meiners, "Production, Distribution, Use and Environmental Impact Potential of Selected Pesticides," Final Report, Contract No. EQC-311, for Council on Environmental Quality, Washington, D.C. (1974).

E. I. du Pont de Nemours and Company is the only manufacturer of bromacil. The manufacturing plant is located in La Porte, Texas and has an estimated total capacity of 20 million pounds per year for all substituted uracils.

A proposed schematic for bromacil production is shown in Figure 1.

A series of substituted uracils is covered by U.S. Patent No. 3,235,357 (Loux, 1966)[1/], but this is primarily a use patent and the method suggested for preparing bromacil is a laboratory method.

The preparation of bromacil is described as follows:

> "A solution of 182 parts of 3-sec-butyl-6-methyluracil in 700 parts of acetic acid containing 82 parts of sodium acetate was treated with 160 parts of bromine. After standing overnight, the mixture, which contained some solid, was evaporated to a solid under reduced pressure. The solid was recrystallized from an ethanol-water mixture to give, as a white crystalline solid, 2-sec-butyl-5-bromo-6-methyluracil melting at 157.5 to 160°C."

Physical Properties of Bromacil

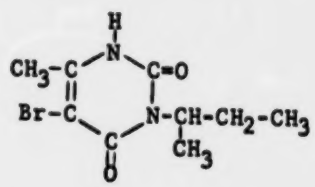
Chemical name: 5-bromo-3-sec-butyl-6-methyluracil

Common name: Bromacil

Trade name: Hyvar® X

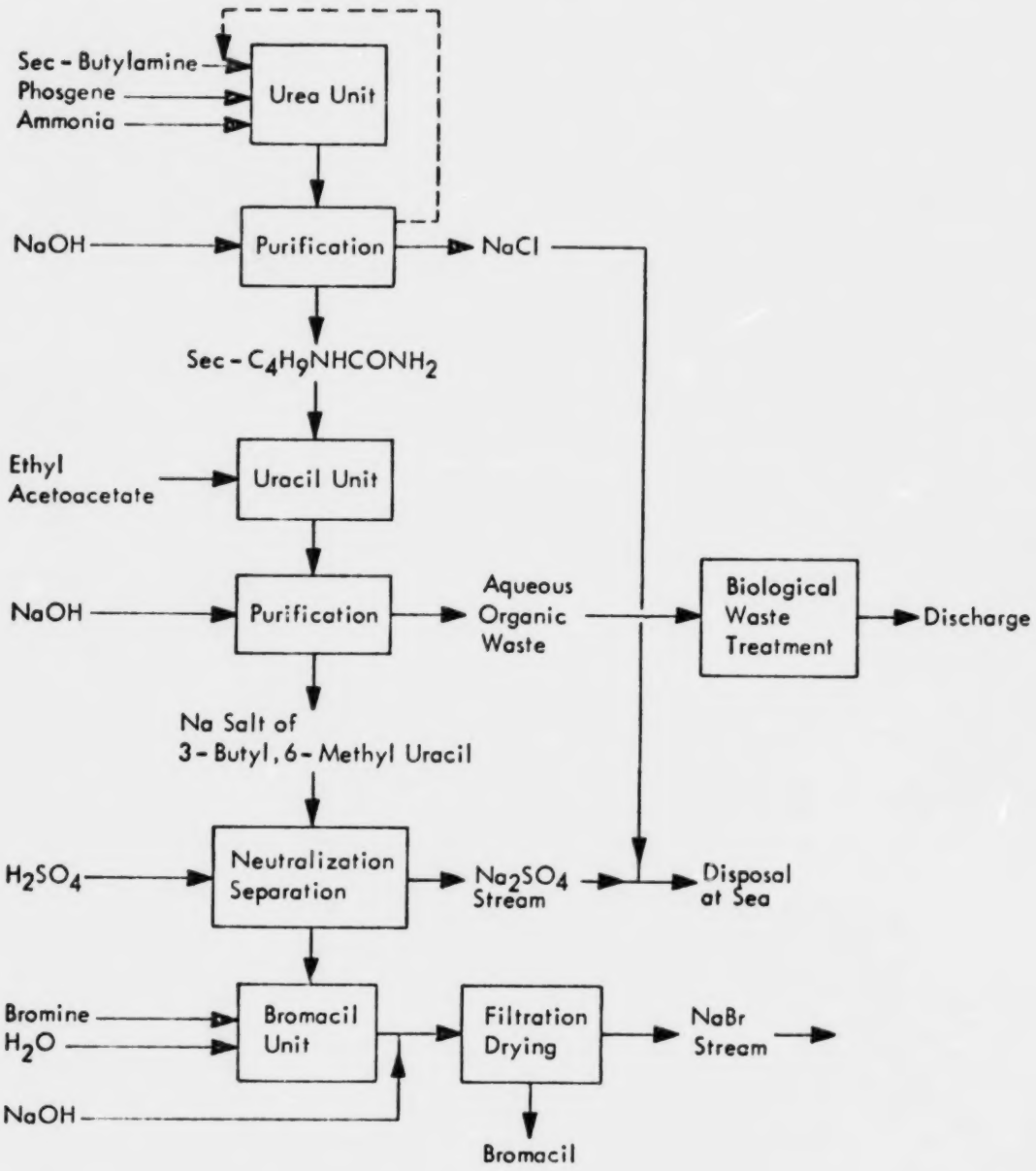
Pesticide class: Herbicide; substituted uracil

Structural formula:



Empirical formula: $C_9H_{13}BrN_2O_2$

1/ Loux, H. M. (to E. I. du Pont de Nemours and Company, Inc.), U.S. Patent No. 3,235,357 (February 15, 1966).



Source: von Rümker et al., op. cit. (1974).

Figure 1. Production schematic for bromacil.

Molecular weight: 261.1

Analysis: C - 41.37%; H - 5.02%; Br - 30.61%; N - 10.73%; O - 12.26%

Physical state: White, odorless, crystalline solid

Melting point: 158-159°C

Vapor pressure: 8×10^{-4} mm Hg at 100°C

Stability: Temperature stable up to melting point, but slowly sublimes at temperatures just below melting point.

Specific gravity: 1.55 25/25°C

Solubility at 25°C:

Solvent	g/100 ml
Absolute ethanol	13.4
Acetone	16.7
Acetonitrile	7.1
Sodium hydroxide (3% aqueous)	8.8
Water	0.0815 (= 815 ppm)
Xylene	3.2

Analytical Methods

This subsection reviews analytical methods for bromacil. The review describes multi-residue methods, residue analysis principles, and formulation analysis principles. Information on the sensitivity and selectivity of these methods is also presented.

Multi-Residue Methods - Multi-residue methods for detecting bromacil are not found in either the Association of Official Analytical Chemists methods manual[1/] or the Pesticide Analytical Manual, Volume I (PAM 1971).[2/] Bromacil has not been reported as a significant residue in any class of food nor is it routinely searched for in the FDA multi-residue analytical system which is used to monitor pesticide residues in food. Adequate individual compound methods exist for measuring bromacil residues. The apparent reason for the absence of bromacil residue data is that the pesticide is not widely used on food and feed items. The absence of bromacil residue data does not mean that it could not be present in food.

1/ Association of Official Analytical Chemists, Official Methods of Analysis of the Association of Official Analytical Chemists, 11th ed., Washington, D.C. (1970).

2/ U.S. Department of Health, Education and Welfare, Food and Drug Administration, Pesticide Analytical Manual, Vol. I (1971).

Residue Analysis Principles - Volume II of the Pesticide Analytical Manual (PAM, 1971)[1] lists two methods of residue analysis for bromacil. The first is the method described by Pease (1966).[2] This method can be used for soil, fruits, vegetables, animal tissue, grain and seed. The sample is first extracted with sodium hydroxide; the extract is acidified with sulfuric acid, and the bromacil is then extracted into chloroform. The chloroform portion is separated and the solvent is evaporated. The residue is redissolved in aqueous sodium hydroxide, acidified, and the bromacil is reextracted into ethyl acetate. The solvent is again evaporated and the residue is finally dissolved in nitromethane. The final determination is made using gas chromatography and a microcoulometric detector. The recoveries are greater than 85%, and the sensitivity is about 0.04 ppm.

The second PAM method is described in Jolliffe et al. (1967)[3]. The method employs a relatively short (13 in.) gas chromatography column and an electron-capture detector. The authors claim the method is simple and fast, but maintains sensitivity and reproducibility. The procedure for the analysis of soils is slightly different from that for leaves or fruit. For both procedures, the initial extraction is performed with an aqueous solution of ammonium sulfate and sodium hydroxide. In soil analysis, the recoveries are 90 to 110%, and sensitivity is about 0.01 ppm. For leaves or fruit, the method is not as accurate; recovery is about 60 to 85%, and sensitivity is 0.1 ppm.

Zweig and Sherma (1972)[4] discuss two additional methods. One is described by Bevenue and Ogata (1970).[5] This method uses gas chromatography with an electron-capture detector and is applicable to plant material, soil and water. Sample preparations are similar to those used by Pease (1966) and Jolliffe et al. (1967). The method differs from that of Pease (1966)--a microcoulometric titrating system is not needed. The method also differs from that of Jolliffe et al. (1967)--a short gas chromatograph is not used. Recoveries of bromacil were 85 to 89%, and the limits of detectability were 0.005 ppm. The second method is that of Gutenmann and Lisk (1968).[6] Their method for bromacil was tested only on residues in soil. The residue was extracted directly into ethyl acetate. The herbicide was then isolated by evaporative co-distillation. Electron affinity detection was employed in the gas chromatographic procedure. Recoveries of bromacil in the 0.04 to 0.4 ppm range ranged from 72 to 90%.

1/ U.S. Department of Health, Education and Welfare, Food and Drug Administration, Pesticide Analytical Manual, Vol. II (1971).

2/ Pease, H. L., "Determination of Bromacil Residues," J. Agr. Food Chem., 14(1):94-96 (1966).

3/ Jolliffe, V. A., B. D. Day, L. S. Jordan, and J. D. Mann, "Method of Determining Bromacil in Soils and Plant Tissues, "J. Agr. Food Chem., 15(1):174-77 (1967).

4/ Zweig, G. and J. Sherma, Analytical Methods for Pesticides and Plant Growth Regulators, Vol. VI: Gas Chromatographic Analysis, p. 603, Academic Press, New York, New York (1972).

5/ Bevenue, A. and J. N. Ogata, "Determination of Bromacil by Gas Chromatography," J. Chromatog., 46(1):110-11 (January 1970).

6/ Gutenmann, W. H. and D. J. Lisk, "Estimation of Residues of Uracil Herbicides by Gas Chromatography After Evaporative Co-Distillation," J. Assoc. Offic. Anal. Chem., 51(3):688-90 (1968).

Formulation Analysis Principles - Pease and Deye (1967)[1/] explain the basis for formulation analysis as follows:

"Bromacil exhibits the properties of a weak acid. It forms water-soluble alkali salts and can be extracted from aqueous acid into nonpolar organic solvents. The material can thus be separated, purified, and concentrated by appropriate extraction techniques.

"The isolated material is most accurately determined by a differential infrared analysis at 13.02 μm, the absorption maximum arising from the uracil configuration of the molecule. Bromacil is too weakly acidic for titration in water, but can conveniently and easily be assayed with good precision by nonaqueous titration.

"Ultraviolet analysis of the extracted material is impractical because of interferences. Gas chromatographic methods are accurate but generally lack the precision of the differential infrared and nonaqueous titration methods."

Pease and Deye (1967) then explain the principle of the differential infrared method:

"The active ingredient, 5-bromo-3-sec-butyl-6-methyluracil, is isolated by extraction with ethyl ether and is determined by differential infrared analysis. In the differential infrared method, a solution of known concentration of pure bromacil is placed in the reference beam of the infrared spectrophotometer, and its absorbance is compared with that of a solution of the unknown placed in the sample beam. To assure maximal precision, the solution is scanned three times at slow speed and high gain, and the average absorbance reading is used."

The standard deviation of this method is approximately 1% in the 40 to 60% concentration of bromacil range, provided there are no extractable ingredients that absorb at the analytical wavelengths.

The principle of the nonaqueous titration method is explained by Pease and Deye (1967):

"The active ingredient, 5-bromo-3-sec-butyl-6-methyluracil, after isolation from possible interfering formulating ingredients, is dissolved in acetone and titrated with tetrabutylammonium hydroxide. The titration is followed potentiometrically with a high impedance pH meter using a glass-modified calomel electrode system."

The precision of this method is ± 0.3%. Other weakly acidic materials may interfere.

1/ Pease H. L. and J. F. Deye, "Bromacil," Analytical Methods for Pesticide, Plant Growth Regulators, and Food Additives, Vol. V: Additional Principles and Methods of Analysis, G. Zweig (ed.), Academic Press, New York (1967).

Composition and Formulation

Bromacil is available in five formulations from the manufacturer:

1. Hyvar® X bromacil weed killer, a wettable powder containing 80% bromacil.
2. Hyvar® X-L bromacil weed killer, a water-soluble liquid containing 2 lb bromacil per gallon (present as lithium salt).
3. Hyvar® X-P brush killer, pellets containing 10% bromacil.
4. Krovar® I weed killer, a wettable powder containing 40% bromacil and 40% diuron.
5. Krovar® II weed killer, a wettable powder containing 53% bromacil and 27% diuron.

Commercial formulators prepare other formulations, including some which contain other pesticides.

Chemical Properties, Degradation and Decomposition Process

Bromacil is a herbicide of a family called substituted uracils. Many members of this family are strong photosynthesis inhibitors.

Bromacil has been shown to be an inhibitor of photosynthesis in many laboratory systems, and this effect is the probable cause of its herbicidal activity. (Hoffmann et al.[1], Hilton et al.[2]).

The lack of activity on nonphotosynthesizing plant tissue was confirmed by Jordan et al.[3]. They found that bromacil had no effect on the dark growth of tobacco callus tissue supplied with an organic energy source, except at much greater concentrations than required for inhibition of photosynthesis.

Couch[4] found that one ppm of bromacil reduced photosynthesis $^{14}CO_2$ - fixation in corn (Zea mays), cotton (Gossypium hirsutum), and soybeans (Glycine Max).

1/ Hoffmann, C. E., J. W. McGahen, and P. B. Sweetser, "Effect of Substituted Uracil Herbicides on Photosynthesis", Nature, 202 (4932):577-8 (1968).

2/ Hilton, J. L., T. J. Monaco, D. E. Moreland, and W. A. Gentner, "Mode of Action of Substituted Uracil Herbicides," Weeds, 112:129-131 (1964).

3/ Jordan, L. S., T. Murashige, J. D. Mann, and B. E. Day, "Effect of Photosynthesis - Inhibiting Herbicides on Nonphotosynthetic Tobacco Callus Tissue," Weeds, 14(2):134-6 (1966).

4/ Couch, R. W. and D. Davis, "Effect of Atrazine, Bromacil and Diquat on 14-CO_2 - Fixation in corn, cotton, and soybeans", Weeds, 14(3): 251-5 (1966).

The chemical name of 5-bromo-3-sec-butyl-6-methyluracil was originally used by Chemical Abstract Services (CAS), and is the one accepted for use on the pesticide label ingredient statement (Caswell, 1972)[1]. CAS now uses the name 5-bromo-6-methyl-3-(1-methylpropyl)-2,4(1H,3H)-pyrimidinedione.

Photochemical Decomposition - Several investigations have been made of the effect of ultraviolet (UV) radiation on herbicides. Jordan et al. (1965)[2] subjected samples of several herbicides to various sources of UV radiation. Three sources of UV radiation were used: far UV (wavelength range, 240 to 260 nm, peak at 253.7 nm); middle UV (275 to 375 nm, peak at 311 nm); and near UV (320 to 450 nm, peak at 360 nm). The lamps emitted approximately 15 w at the peak wavelength. The samples were prepared by allowing solutions (1×10^{-3} molar) to evaporate on 1-in. diameter aluminum planchets. The samples were placed 1 ft from the UV sources.

The results showed that the most extensive decomposition of bromacil was caused by far UV radiation. However, a thin layer of decomposed product apparently protected the lower layers, indicating that very little protection is required to prevent photodecomposition. The author noted that far UV radiation does not occur in natural sunlight. Significant UV radiation above 290 nm occurs in sunlight and the photodecomposition mechanism may be the same at all UV wavelengths, although the rate may vary. Wright (1967) [3] also found that far UV radiation produces more rapid decomposition of bromacil than middle or near UV radiation.

1/ Caswell, R. L., D. E. Johnson, and C. Flack, Acceptable Common Names and Chemical Names for the Ingredient Statement on Pesticide Labels (2nd ed.), Environmental Protection Agency, Washington, D.C. (June 1972).

2/ Jordan, L. S., J. D. Mann, and B. E. Day, "Effects of Ultraviolet Light on Herbicides," Weeds, 13(1):43-46 (January 1965).

3/ Wright, W. L., "Photochemical Breakdown of Herbicides," (Abstract), Proceedings, 20th Southern Weeds Conference, 20:391 (1967).

Hill (1971)[1] reported that, in exposure tests in sunlight and in several practical field tests, bromacil did not appear to be affected adversely by sunlight. However, he presented no details of the analytical method or the extent of exposure.

Kearney et al. (1969)[2] obtained results showing that ultraviolet radiation can greatly reduce the phytotoxicity of bromacil. In seeking a method to decontaminate water supplies, he irradiated various solutions of pesticides in water with a 450-w Hanovia lamp. This lamp is an intense source of UV radiation and emits strongly in the far, middle and near UV. The initial concentration of bromacil was 1 ppm. Kearney used a bioassay for bromacil, but did not report any products formed from the implied photodecomposition.

Degradation in Soil - Zimdahl (1968)[3] studied the kinetics of the degradation of various herbicides in soil. Nine different herbicides were applied at 8 ppm, and temperatures were maintained at either 13.2°C or 31.2°C. Moisture was maintained at about 50% of field capacity, and monthly samples of the soil were analyzed. The following conclusions were reported:

1. The rate of degradation followed a first order rate law.
2. The degradation was probably nonenzymatic.
3. The herbicides appeared to be attacked by chemical hydrolysis at the halogen substitutent. (This conclusion was apparently based upon kinetic data, not analytical data, and no hydrolysis products were reported.)

Thermal Decomposition - Bromacil is stable up to its melting point of 158 to 159°C. However, it begins to sublime at temperatures below its melting point (du Pont, April, 1972)[4]. Bromacil apparently begins to

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1/ Hill, G. D., "Characteristics of Herbicides by Chemical Groups," Proceedings, 23rd Annual California Weed Conference (January 1971).

2/ Kearney, P. C., E. A. Woolson, J. R. Plimmer, and A. R. Isensee, "Decontamination of Pesticides in Soils," Residue Rev., 29:137-149 (1969).

3/ Zimdahl, R. L., "A Kinetic Analysis of Herbicide Degradation in Soil," Diss. Abstr. Int., 29:849-B (1968).

4/ E. I. du Pont de Nemours and Company, Inc., Bromacil Technical Data Sheet, Wilmington, Delaware (April 1972).

decompose above its melting point, but, according to Kennedy et al. (1969)[1/] the decomposition is not total even up to temperatures as high as 1000°C. Table 1 shows weight losses of a commercial formulation of bromacil heated to various temperatures (the exact nature of the formulation was not disclosed).

Table 1. WEIGHT LOSSES ON COMBUSTION OF A COMMERCIAL BROMACIL FORMULATION (PERCENT)

600°C	700°C	800°C	900°C	1000°C
88.8	89.1	89.4	90.5	91.3

Source: Kennedy et al., op. cit. (1969).

The data in Table I is not only an indication of volatalization but also an indication of the decomposition of inorganic carriers or fillers in the formulation. Kennedy et al. (1969) apparently used a solid commercial formulation containing 80% bromacil. Under experimental conditions, the bromacil would most likely volatilize completely, although the contact times were not given.

Kennedy et al. (1972)[2/,3/] identified the volatile products of the combustion of analytical grade bromacil at 900°C as carbon monoxide and carbon dioxide; however, they noted that there were several unidentified products. The sample gas was specifically analyzed for hydrogen bromide, but it was not detected.

In other experiments at the same laboratories, Stojanovic et al. (1972)[4/] subjected various pesticides to thermoshocking, or partial degradation at temperatures below that required for complete destruction. At the temperature employed for bromacil, 250°C for 30 min, the breaking

1/ Kennedy, M. V., B. J. Stojanovic, and F. L. Shuman, Jr., "Chemical and Thermal Methods for Disposal of Pesticides," Residue Rev., 29: 89-104 (1969).

2/ Kennedy, M. V., B. J. Stojanovic, and F. L. Shuman, Jr., "Chemical and Thermal Aspects of Pesticide Disposal," J. Environ. Quality, 1(1):63-65 (1972).

3/ Kennedy, M. V., B. J. Stojanovic and F. L. Shuman, Jr. "Analysis of Decomposition Products of Pesticides" J. Agr. Food Chem., 20(2): 341-3 (1972).

4/ Stojanovic, B. J., Fay Hutto, M. V. Kennedy, and F. L. Shuman, Jr., "Mild Thermal Degradation of Pesticides," J. Environ. Quality, 1(4):397-401 (1972).

of carbon-carbon bonds appeared to be minimal. The authors found that bromacil turned black, and lost 34% of its weight. The remaining product was believed to be 3-sec-butyl-6-methyluracil (infrared spectral analysis). The formation of this product indicates that the bromine substituent was lost.

Other Decomposition Processes - Kennedy et al. (1972) reported that concentrated sulfuric acid was effective in bringing about changes in bromacil but did not elaborate on what the changes were. This is in agreement with the manufacturer's information that bromacil decomposes slowly in strong acid, but is stable in water, aqueous bases, and common organic solvents (du Pont, April, 1972).

Hill (1971) reported the results of a volatilization test. Bromacil was held in an air circulation oven at 120°F for 2 weeks. Losses were less than 0.1%/week.

Occurrence of Bromacil Residues in Food and Feed Commodities

The Food and Drug Administration (FDA) monitors pesticide residues in the nation's food supply as part of two programs--a "total diet: program and a "market basket" study. Much of the data obtained is published, and the literature is voluminous. However, published data reveals that bromacil has not been reported as a significant residue in any food class, nor is it routinely searched for in the FDA's multi-residue analytical system which monitors pesticide residue in food. Adequate individual compound methods exist for measuring bromacil residues. The apparent reason for the absence of bromacil residue data is that the pesticide is not widely used on major food and feed items. The absence of bromacil residue data does not necessarily mean that it could not be present in food.

Acceptable Daily Intake

The acceptable daily intake (ADI) is defined as the daily intake which, during an entire lifetime, appears to be without appreciable risk on the basis of all known facts at the time of evaluation (Lu, 1973)1/. It is expressed in milligrams of the chemical per kilogram of body weight (mg/kg).

1/ Lu, F. C., "Toxicological Evaluation of Food Additives and Pesticide Residues and Their 'Acceptable Daily Intakes' for Man: The Role of WHO, in Conjunction with FAO," Residue Rev., 45:81-93 (1973).

The ADI is established only by the FAO/WHO. Since bromacil is used on so few food crops, the FAO/WHO has not yet determined an ADI for bromacil.

Tolerances

Tolerances for bromacil are within the purview of tolerance procedures for pesticide chemicals established under the Food, Drug, and Cosmetic Act, as amended. Bromacil is primarily a monagricultural herbicide. Most of its uses are commercial and industrial. Only two crop sectors in the United States, citrus fruits and pineapple, have bromacil tolerances. The tolerance for both is 0.1 ppm.1/

1/ Code of Federal Regulations, "USDA Summary of Registered Agricultural Pesticide Chemical Uses," (Vol. I, 1970), Title 40, Part 180,210.

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Pease, H. L., "Determination of Bromacil Residues," J. Agr. Food Chem. 14(1):94-96 (1966).

Pease, H. L., and J. F. Deye, "Bromacil," Analytical Methods for Pesticides, Plant Growth Regulation, and Food Additives, G. Zweig (ed.), Academic Press, New York (1967).

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SUBPART II. B. PHARMACOLOGY AND TOXICOLOGY

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This section reviews pharmacological and toxicological data on bromacil. Subsections present information on acute, subacute and chronic studies in different species of laboratory and domestic animals by various routes of administration. Information is reviewed concerning effects on reproduction and mutagenic effects. There was little available data on behavioral effects, tissue culture studies, oncogenic effects and the effect on humans. The section summarizes rather than interprets scientific data reviewed.

Acute, Subacute and Chronic Toxicity

Acute Oral Toxicity - Rats - The LD50 value for bromacil (as active ingredient in 80% wettable powder) in male rats has been reported in petition data (Zapp, 1965, EPA Pesticide Petition No. 6F0499 Vol. II, and Edson et al., 1965)[1/],[2/] to be 5,200 mg/kg (95% confidence limits 5,024 mg--5,330 mg/kg). Another reported LD50 value was 5,175 mg/kg based on active ingredient (Sherman et al.)[3/].

Acute Inhalation Toxicity - Rats - In each test bromacil was atomized into an inhalation chamber at levels of 2.1 mg/liter and 4.8 mg/liter for 4 hr. There were four test animals for each exposure and the animals were observed for 14 days post exposure. All the animals survived. The symptoms displayed during exposure were rapid and deep respiration and ruffled fur. One of the animals in the 4.8 mg/litter exposure had dried blood around the nose and mouth (Zapp, 1965).

Subacute Oral Toxicity - Rats - Bromacil (80% wettable powder) was given to male rats by intubation as a 15% aqueous suspension five times a week for 2 weeks. Five out of six animals survived 10 daily doses of 1,035 mg/kg of body weight. Four out of six animals died after four to five doses of 1,500 mg/kg/day whereas there were no deaths when 10 daily doses of 650 mg/kg of bromacil were administered. The 650 mg/kg and the 1,035 mg/kg levels did produce some pathological changes in the livers (focal cell hypertropy and hyperplasia) of animals which were sacrificed after 10 days exposure to the pesticide. These symptoms were no longer evident in animals after a 14-day recovery period (Zapp, 1965).

1/ Zapp, J. A., Jr., Report on Bromacil, EPA Pesticide Petition No. 6F0499, Vol. II, 1965.

2/ Edson, E. F., D. M. Sanderson, and D. N. Noakes, "Acute Toxicity Data for Pesticides (1964)," World Rev. Pest Con., 4:36-41 (1965).

3/ Sherman, H., et al., Report 12-66, EPA Pesticide Petition No. 6F0499, Vol. I (1963).

Chronic Oral Toxicity - Rats - Bromacil (80% wettable powder containing 83.0% AI) was fed to rats for a 2-year period (Sherman, et al., 1963).

Group Number	Level of Bromacil in Diet
I (control)	GPLC[a/] + 1% Co[b/]
I-A (control)	GPLC + 1% Co
II	GPLC + 1% Co + 0.005% (50 ppm)
III	GPLC + 1% Co + 0.025% (250 ppm)
IV	GPLC + 1% Co + 0.125% (1,250 ppm)

a/ Ground Purina Laboratory Chow.
b/ Corn oil.

Hematology examinations and urinalysis were run on six males and six females once a month for the first 3 months and every 3 months thereafter. Biochemical tests of six males and six females of each group were run at the end of 1, 3, 6, 9, 12 and 24 months. At the end of 3, 6 and 12 months of feeding, the number of animals of each sex was reduced to 32, 30 and 24, respectively. The brain, heart, lung, liver, spleen, kidney, testis, stomach, adrenals and pituitary were weighed and pathological examinations were made on 26 other body tissues. The daily dosage for male rats ranged from 154.2 to 38.7 ppm (4:1) and for female rats 143.3 to 39.3 ppm (3.6:1). It is normal for dosage to decrease since rats consume less per body weight as they grow larger.

The actual amounts of bromacil ingested in the various diets are shown in Table 2. Mortalities which occurred within the group are shown in Table 3.

The female rats on the 0.125% bromacil diet suffered weight retardation for the first and second year. There were no clinical signs of toxicity. During the first year, three control animals died and there were three deaths in the treated groups.

Table 2. CONSUMPTION OF BROMACIL

Days of test	0.005% (mg/kg)	0.025% (mg/kg)	0.125% (mg/kg)
0.7	6.08	30.2	154.2
105-112	2.27	11.3	56.4
203-210	1.83	9.6	47.6
490-504	1.55	8.0	39.7
602-616	1.46	--	37.9
714-728	1.37	6.56	38.7

Source: Sherman, et al., op. cit. (1963).

Table 3. MORTALITY OF RATS CONSUMING BROMACIL

Dietary level (%)	Killed by design		Killed extremis		Found dead		Survived 24 months	
	Male	Female	Male	Female	Male	Female	Male	Female
0	11	12	2	8	14	3	9	13
0	10	12	6	8	9	6	11	10
0.005	12	12	8	6	8	9	8	9
0.025	12	11	3	8	9	5	12	12
0.125	12	12	8	3	8	4	10	17

Source: Sherman et al. op. cit. (1963).

There were no unusual alterations in the hematology, urinalysis and clinical chemistry evaluations. No gross pathological lesions were observed. There appeared to be a dose-related effect on the thyroid. Focal light cell hyperplasia and focal follicular cell hyperplasia were noted somewhat in controls but observed slightly more often in the thyroids of rats at the high dose. One follicular cell adenoma occurred in a female rat at the highest dose level. There were no excessive accumulations of residues in the tissues.

Another investigation (Zapp, 1965) involved a 90-day oral toxicity test of bromacil in rats. Ten male and 10 female rats were placed in each group. The dosages were as follows:

Group Number	Dietary level	
	ppm	Estimated[a/] (mg/kg)
1	0	--
2	50	2.5
3	500	25.0
4	2,500 (0-6 weeks)	125.0
	5,000 (7-10 weeks)	250.0
4A	5,000 (11-13 weeks)	250.0
4B	6,000 (11th week)	300.0
	7,500 (12-13 weeks)	375.0

a/ Estimation by reviewer based on a 500-g rat consuming 25 g of diet a day.

No deaths occurred and no signs of toxicity were observed. The male rats in Groups 4A and 4B exhibited a reduced growth rate during the last 3 weeks of the test. The hematology and urinalysis values were within normal limits. There were no pathological changes of significance in the groups receiving 50 and 500 ppm of bromacil. For the groups receiving 5,000 ppm and above, there were microscopic changes in the thyroids, suggestive of increased glandular activity.

Acute Oral Toxicity - Dogs - An attempt was made to determine the acute oral toxicity of bromacil in dogs (Hazelton Laboratories, 1966).[1/] Bromacil (80% wettable powder) as a massive dose (5 g/kg) was given by capsule to a dog. The dog exhibited excessive emesis, copious salivation, weakness, loss of coordination, excitability, diarrhea and mydriasis. Forty-eight hr later, six divided doses were given and repeated emesis, salivation, mydriasis and sanguineous diarrhea occurred.

The second dog was given two oral doses of bromacil 5 days apart (200 and 250 mg/kg); each dose evoked repeated emesis. A lethal dose was not obtained in the dog because of emesis.

Chronic Oral Toxicity - Dogs - A 2-year feeding study of bromacil in dogs was also conducted.[2/] Six dogs (three male and three female) in each of four groups received the following dosages of dietary bromacil:

Group 1	0.0% (Control)
2	0.005%
3	0.025%
4	0.125%

The dogs in the 0.125% level declined in weight at the start of the experiment and then weights stabilized between 1 to 1.5 kg lower than the other dogs in the test. Throughout the duration of the test, clinical signs, such as appearance, rectal temperature, pulse and respiration, appeared to be normal.

The only death loss was an animal on the 0.005% dosage level. Illness and death were judged not to be associated with the test compound. A subdural hemorrage was observed in the spinal column. Throughout the course of the study, there were no significant alterations in hematology, urinalysis and blood chemistry. There was no effect on organ weight and no significant pathology occurred at the microscopic level. There was no evidence of excessive accumulation of residues in the tissues.

Other Toxicological Evaluations -

Dermal - Acute Toxicity - Rabbits - An acute skin absorption toxicity test was made on rabbits. Bromacil was applied to the intact skin (clipped) of three male rabbits. A 70% aqueous paste was made up to supply 5,000 mg/kg. The contact period was 24 hr and the animals were observed for 14 days. There were no signs of toxicity or gross pathological changes. The approximate lethal dose (ALD) was estimated to be greater than 5,000 mg/kg (Zapp, 1965).

1/ Hazelton Laboratories, Report on Bromacil, EPA Pesticide Petition No. 6F0499, Vol. II, 1966.

2/ Bromacil Report, EPA Pesticide Petition No. 6F0499, Section C.

Dermal - Sensitization Test - Guinea Pigs - Ten guinea pigs were prepared by clipping fur and abrading the skin. A 50% suspension of bromacil in 1% aqueous Duponal PT was applied to these areas for 24 hr. Animals with abraded skin were exposed 3 times a week for 3 weeks. They were reexposed after 2 or 3 weeks rest. There appeared to be no induced skin sensitivity. The skin of the younger animals was mildly irritated (Zapp, 1965).

Eye Irritation - Ten milligrams of bromacil (0.1 ml of a 10% suspension in mineral oil) was placed on the surface of two rabbits' eyes. One eye of each rabbit was then washed for 1 minute with tap water, starting 20 seconds after contact. The other eye of each rabbit was not washed. A mild temporary conjunctivitus was observed in both washed and unwashed eyes. No corneal damage was observed in either washed or unwashed eyes. The experiment was repeated as above, with identical results, using 50% wettable powder (Zapp,1965).

Toxicity to Domestic Animals - Palmer and Radeleff (1969)[1/] have evaluated the toxicity of multiple-dosing of bromacil in cattle, sheep, and chickens. The results of these tests are given in Table 4.

One dose (250 mg/kg) administered to a yearling calf produced poisoning with survival and a 14% weight loss.

The results with sheep were varied. A dose of 50 mg/kg given 10 times by drench produced no effect. When the dosage was given by capsule, the animal was poisoned, survived and sustained an 8% weight loss. A 100 mg/kg dosage in capsule form had no observable effects, while a drench produced poisoning. At the 250 mg/kg level, poisoning occurred after the third dose, and, by capsule, eight doses were consumed before poisoning occurred.

Chickens appeared to tolerate a dose of 500 mg/kg. However, there was a significant reduction in weight gain. Weight gain was also reduced slightly at the 250 mg/kg level.

The authors commented that bromacil application rates range from 1.6 to 20 lb/acre. They felt that a rate of 20 lb/acre would not be hazardous to cattle or chickens, but rates of application in excess of 5 lb/acre would be hazardous to sheep.

Palmer (1964)[2/] reported that the administration of five doses of 250 mg/kg each to sheep of bromacil produced tympany and stilted gait within 4 hr after administration of the first dose. After five doses of bromacil the animal slowly recovered and had marked lameness. When the dosage was reduced to 100 mg/kg, the administration of 11 treatments produced no clinical symptoms but there was an 11% weight loss.

1/ Palmer, J. S., and R. D. Radeleff, "The Toxicity of Some Organic Herbicides to Cattle, Sheep, and Chickens," USDA Prod. Res., Report No. 106: 1-26 (1969).

2/ Palmer, J. S., "Toxicity of Methyluracil and Substituted Urea and Phenol Compounds to Sheep," Amer. Vet. Med. Assoc. J., 145:787-789 (1964).

Table 4. RESULTS OF MULTIPLE ORAL DOSING OF BROMACIL[a/] IN CATTLE, SHEEP, AND CHICKENS[b/]

Animal and dosage received (mg/kg)	Doses	Means of dosing	Results and remarks
Cattle:	Number		
100	10	Drench	NIE[c/]
100	10	Capsule	NIE
250	10	Capsule	Poisoned after one dose and survived, 14% weight loss
Sheep:			
25	10	Drench	NIE
50	10	Capsule	Poisoned and survived, 8% weight loss
50	10	Drench	NIE
100	10	Capsule	NIE
100	10	Drench	Poisoned and survived, 9% weight loss
250	5	Drench	Poisoned after three doses survived, 9% weight loss
250	10	Capsule	Poisoned after eight doses survived, 8% weight loss
Chickens[d/]			
100	10	Capsule	49% weight gain
250	10	Capsule	39% weight gain
500	10	Capsule	24% weight gain
Controls			48% weight gain

a/ Hyvar® X, 80% wettable powder.
b/ Adapted from Palmer and Radeleff (1969).
c/ NIE indicates no ill effects apparent.
d/ Average results of five treated chickens.

Tympanites is commonly encountered in cattle and sheep dosed with bromacil. Williams et al. (1963)[1] found that certain chlorinated hydrocarbons, organophosphates, and carbamate compounds stimulate gas production *in vitro* by rumen holotrich protozoa whereas these compounds had no appreciable effect when rumen bacteria inoculum was used. In these experiments total gas production was measured by manometric techniques. No attempt was made to determine the chemical composition of the gases produced. Kutches et al. (1970)[2] studied the effect of a number of insecticides and herbicides on *in vitro* rumen fermentation. The parameters of investigation included dry matter disappearance, volatile fatty acid production, and changes in protozoal numbers. With dosages of 0.0, 100, 250, 500, 750, and 1,000 ppm, the respective values for percent *in vitro* dry matter disappearance were: 28.5, 28.4, 27.7, 25.0, 22.8 and 18.5. The volatile fatty acid production was not affected by 1,000 ppm of bromacil. The numbers of ciliated protozoa increased slightly in the presence of 100 ppm bromacil but decreased sharply as the bromacil concentration exceeded 500 ppm.

The results indicated that high concentration of bromacil (1,000 ppm) significantly affected rumen microbial processes. No significant effects in *in vitro* forage digestability were noted at lower concentrations (250 ppm and below). Since feedstuff contamination is usually less than 250 ppm, it was concluded that bromacil would have negligible affect on rumen digestability or other associative rumen function.

Symptomology and Pathology Associated with Mammals - In the dog, massive doses of bromacil caused excessive emesis, copious salivation, weakness, lack of coordination, excitability, diarrhea, and mydriasis (Hazelton Laboratories,1966). In the rat, a near-toxic dose of bromacil caused an initial weight loss of the animal. In acute toxicity cases the respiration rate became very rapid. Discomfort, prostration, salivation and lack of coordination occurred (Zapp, 1965).

In cattle and sheep, bromacil poisoning caused a weight loss, anorexia and depression, tympanites, and incoordinated gait (Palmer, 1964; Palmer and Radeleff, 1969).

1/ Williams, P. P., J. D. Robbins, J. Gutienez, and R. E. Davis, "Rumen Bacterial and Protozoal Responses to Insecticides Substrates," Appl. Microbiol., 11:517-522 (1963).

2/ Kutches, A. J., D. C. Church, and F. Duryee, "Toxicological Effects of Pesticides on Rumen Function *in Vitro*," J. Agr. Food Chem., 18(3): 430-433 (1970).

Metabolism

Absorption - Bromacil is apparently not excreted via the gastrointestinal tract of cows, since Gutenmann and Lisk (1970)[1/] found no bromacil in feces of cows fed 5 and 30 ppm bromacil in the feed for 4 days.

Excretion - Gardiner et al. (1969)[2/] found that rats fed 1,250 ppm bromacil for 1 month excreted five to six metabolites in the urine, the main one being 5-bromo-3-sec-butyl-6-hydroxymethyluracil. 5-Bromouracil was not found as a product of bromacil metabolism.

Urine samples from workers at two different locations in a bromacil production plant were analyzed for bromacil and its metabolites. The results indicated that bromacil was metabolized by man in a manner similar to that in rats (bromacil was found and 5-bromo-3-sec-butyl-6-hydroxymethyl-uracil was found to be the principal metabolite). No 5-bromouracil was found in either hydrolyzed or nonhydrolyzed urine samples from humans (Du Pont, 1966).[3/]

Biotransformation - Gardiner et al. (1969) found six metabolites of bromacil in the urine of rats fed 1,250 ppm bromacil for 1 month. The primary metabolite, 5-bromo-3-sec-butyl-6-hydroxymethyluracil was present in the urine as a conjugate which was hydrolyzed with β-glucuronidase-arylsulfatase enzyme solution.

Additional metabolites found in lesser quantities were 5-bromo-3-(2-hydroxy-1-methylpropyl)-6-methyluracil, 5-bromo-3-(2-hydroxy-1-methylpropyl)-6-hydroxy-methyluracil, 3-sec-butyl-6-hydroxymethyluracil, 5-bromo-3-(3-hydroxy-1-methylpropyl)-6-methyluracil, 3-sec-butyl-6-methyluracil, and an unknown bromine-containing compound of mol. wt 339.

McGahen and Hoffmann (1963a)[4/] found that bromacil was not incorporated into Escherichia coli DNA. These authors reported (1963b)[5/] similar findings in mice.

1/ Gutenmann, W. H., and D. J. Lisk, "Metabolism and Excretion of Bromacil in Milk of Dairy Cows," J. Agr. Food Chem., 18(1):128-129 (1970).

2/ Gardiner, J. A., R. W. Reiser, and H. Sherman, "Identification of the Metabolites of Bromacil in Rat Urine," J. Agr. Food Chem., 17(5): 967-973 (1969).

3/ Du Pont de Nemours Co., Supplementary Report on Bromacil, EPA Pesticide Petition No. 6F0499 (1966).

4/ McGahen, J. W., and C. E. Hoffmann, "Action of 5-Bromo-3-sec-butyl-6-methyluracil on Escherichia coli 15T," Nature, 200(4906):571-572 (1963a).

5/ McGahen, J. W., C. E. Hoffmann, "Action of 5-Bromo-3-sec-butyl-6-methyluracil as Regards Replacement of Thymine in Mouse DNA," Nature, 199(4895):810-811 (1963b).

Effect on Reproduction

The effect of bromacil on reproduction in the rat has been reported. During a 2-year chronic toxicity study, 12 male and 12 female rats each were allowed to continue their regular feeding regimin and reproduce. One of the groups continued to be fed the control diet. The test group continued to consume 0.025% bromacil in the diet. The original rats were called the F_0 generation. The first litter produced from this group became the F_{1a} generation and the second mating produced the F_{1b} generation. The F_{1b} litter was maintained on the same diet and at 100 days of age they were mated to yield the F_{2a} and F_{2b} litters.

There were no marked differences between the reproductive performance of the control and test animals. There were no deformed young. The fertility, gestation, viability and lactation indices were not significantly different. Furthermore, there were no gross or microscopic pathological differences.1/

Teratogenic Effects

There were no deformities found in the previously cited reproductive study on rats.

A study was made of the effects of bromacil on reproduction in the rabbit (Paynter, 1966).2/ Bromacil (80% wettable powder) was fed to New Zealand white rabbits that had an initial weight of 3.0 to 4.7 kg. The groupings and dosages were as follows:

Group number	Number of rabbits	Dietary level of bromacil (ppm)
1 (Control)	9	0
2	9	50
3	8	250

The females were bred and the above dosages were administered starting with the eighth day of pregnancy and continuing through the 16th day. The does were returned to the untreated basal diet on the 17th day. On the 28th or 29th day after breeding, three does each from both the control and 50 ppm diet groups were sacrificed. Four does on the 250 ppm diet were killed. After parturition, all the remaining does were killed and one-third of the young was prepared for tissue clearing to observe any skeletal defects.

No gross manifestations of teratogenic effect were observed in the fetuses and there were no abnormal bone structures.

1/ Bromacil Report, EPA Pesticide Petition No. 6F0499, Section C.
2/ Paynter, O. E., Hazleton Report, Ref. Mro-879, 1966, EPA Pesticide Petition No. 6F0499, Vol. II.

Behavioral Effects

No studies were found in the literature concerning the behavioral effects of bromacil.

Toxicity Studies with Tissue Culture

No information was found on toxicity studies with tissue cultures.

Mutagenic Effects

Because of the possibility that bromacil (5-bromo-3-sec-butyl-6-methyluracil) could be metabolized in vivo to the potent mutagen, 5-bromouracil, experiments have been conducted to determine if bromacil yields mutagenic effects in laboratory animals and to determine whether 5-bromouracil can be detected as a bromacil metabolite.

No 5-bromouracil was detectable in either urine from bromacil production plant works (Du Pont, 1966) or in urine of rats fed bromacil (Gardiner et al., 1969).

McGahen and Hoffmann (1963b) could not detect bromacil in mouse DNA. These same authors evaluated the action of bromacil on Escherichia coli 15T using labeled bromacil. In growth experiments, bromacil was not inhibitory to E. coli 15T. Escherichia coli 15T is a thymine-requiring mutant. E. coli 15T cells in the log phase were exposed to 10 microcuries of labeled bromacil for various periods, chilled and harvested. The cells were washed with water and cold 5% trichloroacetic acid. Bromacil was readily washed from the cells. Furthermore, no radioactivity was detected in the DNA of cells exposed to bromacil.

McGahen and Hoffman (1966)[1/] further examined the mutagenic effects of bromacil on bacteriophage. From their earlier work it was not completely ruled out that there may be indirect mutagenic effect. They used mutant AP72, E. coli B and E. coli K12 (λ) organisms in a back mutation rate study. They observed no mutagenic effect of bromacil. The other substituted 5-bromouracils did not appear to be mutagenic. The explanation was given that the alkyl substitution prevents incorporation of bromacil into DNA or the precursors.

Andersen et al. (1972)[2/] has evaluated 110 herbicides for their ability to induce point mutations in one or more of four different microbial systems. In one test utilizing eight histidine requiring mutants of Salmonella typhimurium, bromacil tested negative to reversion to histidine independence. The effect of bromacil in the induction of the r II mutants of T4 bacteriophage was not different from the control. An evaluation was also made on

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1/ McGahen, J. W., and C. E. Hoffman, "Absence of Mutagenic Effects of 3- and 6-Alkyl-5-bromouracil Herbicides on a Bacteriophage," Nature (London), 209(5029):1241-1242 (1966).

2/ Andersen, K. J., E. G. Leighty, and M. T. Takahashi, "Evaluation of Herbicides for Possible Mutagenic Properties," J. Agr. Food Chem., 20(3):649-656 (1972).

the reversion of the guanine-cytosine transition r II mutant AP72. In general, the herbicides evaluated were not mutagenic in this test system.

Siebert and Lemperle (1974)[1] found that bromacil did not induce mitotic gene conversion in a diploid strain of the ascomycete Saccharomyces cerevisiae heteroallelic at two loci in a test which reacts very sensitively to compounds that induce base-pair substitution as well as frame-shift mutations.

Epstein et al. (1972)[2] found that bromacil in the dominant lethal assay in mice, when administered either by intraperitoneal injection as a single dose of 150 mg/kg or by gavage for five successive doses of 750 mg/kg and 1,000 mg/kg, was not mutagenic.

Ficsor and Nii Lo Piccolo (1972)[3] found bromacil was not mutagenic by the Bacterial-plate assay method. It was inactive in its ability to revert two E. coli lac - amber mutants to the lactose - fermenting phenotype and a cys - and two len - auxotrophs to prototrophy.

Oncogenic Effects

A follicular cell adenoma was found in a female rat that was retained on a long-term study consuming 0.125% bromacil in the diet (Lawless)[4] During the 2-year chronic toxicity studies in dogs and rats, discussed previously, no evidence of oncogenic effects due to bromacil administration was observed in any of the test animals (Sherman, et al., 1966; Zapp, 1965).

Effect on Humans

No information was found on the effect of bromacil to humans on an acute basis, under field conditions, or in the manufacturing process.

1/ Siebert, D. and E. Lemperle, "Genetic Effects of Herbicides: Induction of Mitotic Gene Conversion in Saccharomyces cerevisiae," Mutation Research,(22):111-120 (1974).

2/ Epstein, S. S., et. al., "Detection of Chemical Mutagens by the Dominant Lethal assay in the Mouse," Toxicol. Appl. Pharmacol.,(23):288-325 (1972).

3/ Ficsor, G. and G. M. Nii Lo Piccolo, "Survey of Pesticides for Mutagenicity by the Bacterial - Plate Assay Method," Newslett. Environ. Mutagen Society,(6):6-8 (1972).

4/ Lawless, E. W., Report on Bromacil, EPA Pesticide Petition No. 6F0499, Vol. I.

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Andersen, K. J., E. G. Leighty, and M. T. Takahashi, "Evaluation of Herbicides for Possible Mutagenic Properties," J. Agr. Food Chem., 20(3):648-656 (1972).

Bromacil Report, EPA Pesticide Petition No. 6F0499, Section C.

Du Pont de Nemours and Co., Supplementary Report on Bromacil, EPA Pesticide Petition No. 6F0499 (1966).

Edson, E. F., D. M. Sanderson, and D. N. Noakes, "Acute Toxicity Data for Pesticides (1964)," World Rev. Pest Con., 4:36-41 (1965).

Epstein, S. S., et. al., "Detection of Chemical Mutagens by the Dominant Lethal Assay in the Mouse," Toxicol. Appl. Pharmacol., 23: 288-325 (1972).

Fiscor, G., and G. M. Nii Lo Piccolo, "Survey of Pesticides for Mutagenicity by the Bacterial - Plate Assay Method," Newslett. Environ. Mutagen Society, (6):6-8 (1972).

Gardiner, J. A., R. W. Reiser, and H. Sherman, "Identification of the Metabolites of Bromacil in Rat Urine," J. Agr. Food Chem., 17(5):967-973 (1969).

Gutenmann, W. H., and D. J. Lisk, "Metabolism and Excretion of Bromacil in Milk of Dairy Cows," J. Agr. Food Chem., 18(1):128-129 (1970).

Hazelton Laboratories, Report on Bromacil, EPA Pesticide Petition No. 6F0499, Vol. II, (1966).

Kutches, A. J., D. C. Church, and F. Duryee, "Toxicological Effects of Pesticides on Rumen Function in Vitro," J. Agr. Food Chem., 18(3):430-433 (1970).

Lawless, E. W., Report on Bromacil, EPA Pesticide Petition No. 6F0499, Vol. I.

McGahen, J. W., and C. E. Hoffmann, "Absence of Mutagenic Effects of 3- and 6-Alkyl-5-bromouracil Herbicides on a Bacteriophage," Nature (London), 209(5029):1241-1242 (1966).

McGahen, J. W., C. E. Hoffmann, "Action of 5-Bromo-3-sec-butyl-6-methyluracil as Regards Replacement of Thymine in Mouse DNA," Nature, 199(4895): 810-811 (1963b).

McGahen, J. W., and C. E. Hoffmann, "Action of 5-Bromo-3-sec-butyl-6-methyl-uracil on Escherichia coli 15T," Nature, 200(4906):571-572 (1963a).

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Paynter, O. E., Hazleton Report, Ref. Mro-879, 1966, EPA Pesticide Petition No. 6F0499, Vol. II.

Sherman, H., et al., Report 12-66, EPA Pesticide Petition No. 6F0499, Vol. I (1963).

Siebert, D. and E. Lemperle, "Genetic Effects of Herbicides: Induction of Mitotic Gene Conversion in Saccharomyces cerevisiae," Mutation Research, 22:111-120 (1974).

Williams, P. P., J. D. Robbins, J. Gutienez, and R. E. Davis, "Rumen Bacterial and Protozoal Responses to Insecticides Substrates," Appl. Microbiol., 11:517-522 (1963).

Zapp, J. A., Jr., Report on Bromacil, EPA Pesticide Petition No. 6F0499, Vol. II, (1965).

SUBPART II. C. FATE AND SIGNIFICANCE IN THE ENVIRONMENT

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This section contains data on the environmental effects of bromacil, including effects on aquatic species, wildlife, beneficial insects, soil, water, air, and nontarget plants. The section summarizes rather than interprets data reviewed.

Effects on Aquatic Species

Fish - TLm values for Bluegill sunfish, Rainbow trout, and carp, based on an 80% formulation, indicate a low order of fish toxicity:[1]

Bluegill sunfish

TLm for 24 hr. - 103 ppm
TLm for 48 hr. - 71 ppm

Rainbow trout

TLm for 24 hr. - 102 ppm
TLm for 48 hr. - 75 ppm
TLm for 72 hr. - 38 ppm

Carp

TLm for 24 hr. - 164 ppm
TLm for 48 hr. - 164 ppm

Yoshida and Nishiuchi[2] list the 48 hour TLm values for carp, Japanese goldfish and killifish as 10-40 ppm in each instance. The 48 hour TLm value for loach is $>$ 40 ppm and for tadpole, 230 ppm. The 72 hour value for crawfish is 40 and the 3 hour value for the waterflea is $>$40. Data on the effects of bromacil to fishes under field conditions appears to be nonexistent. Registered labels of bromacil-containing commercial pesticides do not carry any warning or caution statements regarding fish toxicity.

Lower Aquatic Organisms - Hoffman (1973),[3] in a report on the mode of action of bromacil and related uracils, stated that a monuron-resistant strain of Euglena showed similar resistance to Bromacil; the resistant strain was not affected by bromacil at 40 ppm, and only partially inhibited at 100 ppm. By comparison, a wild strain of Euglena was markedly inhibited at 2 ppm and completely inhibited at 10 ppm. Neither strain was affected by bromacil in the dark, indicating that inhibition of photosynthesis is one of the mechanisms of phytotoxic actions of bromacil. No other data was found on the interactions between bromacil and lower aquatic organisms.

1/ E. I. du Pont de Nemours and Company, Inc., Personal communication (1974).

2/ Yoshida, K., and Y. Nishiuchi, "Toxicity of Pesticides to Some Water Organism" Bull of Agr. Chem Inspect. Stn. (Tokyo)12: 122-128 (1972).

3/ Hoffman, C. E., "The Mode of Action of Bromacil and Related Uracils," Second International Conference of Pesticide Chemical Proceedings, (1971). In: Ashton and Crafts, Mode of Action of Herbicides, John Wiley & Sons, pp. 430-431 (1973).

Effects on Wildlife

No data was found regarding laboratory experiments on the toxicity of bromacil to wildlife, or the effects of bromacil to wildlife under field conditions. E. I. du Pont de Nemours (1974) reported that the eight-day dietary LC_{50} of Bromacil for both the mallard duck and the bobwhite quail is greater than 10,000 ppm.

The Handbook of Toxicity of Pesticide to Wildlife (Tucker and Crabtree, 1970)[1/] contains no entries on bromacil.

Pimentel's summary on "Ecological Effects of Pesticides on Nontarget Species" (1971)[2/] does not include any data on the effects of bromacil on wildlife or other nontarget species.

Effects on Insects

Bromacil was tested as a spray at 10,000 ppm against housefly, roach, aphid (systemic) and mite and was found to be totally lacking in insecticidal and acaricidal activity Anderson et al., (1971).[3/]

In laboratory and field studies (mostly spraying) on the effects of honey bees, Aphis mellifera L., conducted in California between 1950 and 1971, bromacil (Hyvar ®) was listed as a "relatively non-toxic" herbicide (Anderson et al., 1971). Atkins et al. (1973)[4/] also reported that bromacil (Hyvar® X) is a relatively nontoxic pesticide with a 1.20% mortality at 193.38 micrograms per honey bee.

Effects and Residues in the Soil

Interactions with Lower Terrestrial Organisms - Torgeson and Mee (1967)[5/] studied the microbial degradation of bromacil. In laboratory tests, soils having no history of exposure to bromacil were treated either with 40 ppm of bromacil in a soil perfusion system, or by mixing bromacil at rates up to 200 lb AI/acre. After incubation, fungi and bacteria were isolated from the treated soil by use of a dilution plate technique. Fifty-five

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1/ Tucker, R. K., and D. G. Crabtree, Handbook of Toxicity of Pesticides to Wildlife, Bureau of Sport Fisheries and Wildlife, Denver Wildlife Research Center, Resource Publication No. 84 (1970).

2/ Pimentel, D., "Ecological Effects of Pesticides on Nontarget Species," Executive Office of the President, Office of Science and Technology, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. (1971).

3/ Anderson, L. D., E. L. Atkins Jr., H. Nakakihara and E. A. Greywood, Toxicity of Pesticides and Other Agricultural Chemicals to Honeybees, U.S. Department of Agriculture, Agricultural Extension Service Report, University of California Press, Berkeley, Calif. (1971).

4/ Atkins, E. L., E. A. Greywood, and R. L. Macdonald, Toxicity of Pesticides and other Agricultural Chemical to Honeybees, U.S. Department of Agriculture, Agricultural Extension Service Report, University of California Press, Berkeley, Calif. (1973).

5/ Torgeson, D. C., and H. Mee, "Microbial Degradation of Bromacil," Northeastern Weed Control Conference Proceedings, 21:584 (1967).

fungal and 73 bacterial cultures were studied in regard to their ability to degrade bromacil by growing them in a Czapek-Dox broth containing 20 ppm of bromacil. The amount of bromacil remaining was periodically determined by a bioassay technique sensitive to less than 1 ppm of bromacil, using buckwheat as the test organism. None of the bacteria degraded bromacil; but four of the fungi exhibited this capability. The most active of these, Penicillium paraherquei, was studied further. No signigicant amounts of bromacil were detectable 15 to 20 days after Czapek-Dox broth containing 20 ppm of the herbicide had been inoculated with this fungus.

Sterile soil treated with bromacil at the rate of 3.1 lb AI/acre was still toxic to buckwheat after 56 days. No herbicidal effects were detected 21 days after treatment with 6.2 lb AI/acre, or 28 days after treatment with 12.5 lb AI/acre in sterile soil inoculated with P. paraherquei. The herbicidal effectiveness of bromacil applications at 25 and 50 lb AI/acre was reduced to 50 and 80%, respectively, after 56 days.

In liquid and solid Czapek-Dox media, P. paraherquei grew normally at concentrations of bromacil up to 200 ppm. At higher concentrations of bromacil, growth of the fungus was slower and abnormal in appearance. The organism failed to grow in a liquid mineral salts medium containing bromacil as the sole carbon and nitrogen source. A variant of P. paraherquei isolated from liquid media containing 800 to 1,000 ppm of bromacil appeared to be capable of growing slowly on bromacil as the sole substrate.

Pancholy and Lynd (1969)[1/] studied the interactions between bromacil and plants, cultures of fungi, and nitrification in the laboratory. In Eufaula sand, bromacil reduced the growth of oat seedlings at concentrations of 0.25 to 1.0 ppm, and the growth of sorghum seedlings at concentrations of 1.0 to 4.0 ppm. Organic matter amendments added to the sand at rates of 1, 2, and 4 ppm significantly reduced the phytotoxicity of bromacil to both oats and sorghum. Oats were more sensitive than sorghum; at 0.25 ppm, the growth of sorghum was not adversely affected by bromacil.

Ten soil fungi (Aspergillus tamarii, A. niger, A. flavus, A. oryzae, Curvularia lunata, Mucor pusillus, Trichoderma viride, Penicillium funiculosum, P. brevicompactum, and Myrothecium verucaria) were cultured on liquid broth media with bromacil levels of 0, 250, 500, 1,000, and 5,000 ppm for 5 days at 22 to 28°C. Bromacil up to 2,000 ppm did not inhibit the growth of the fungi, except A. niger, which was inhibited by bromacil levels less than 1,500 ppm. This fungitoxic effect was partially offset by increasing the inorganic nitrogen levels to 500 ppm, and/or by 1,000 ppm of presynthesized growth factor additive (cyanocobalamin, yeast extract, peptone). Bromacil at 100 ppm reduced nitrification temporarily.

1/ Pancholy, S. K., and J. Q. Lynd, "Bromacil Interactions in Plant Bioassay, Fungi Cultures, and Nitrification," Weed Sci., 17(4): 460-463 (1969).

Wehr and Klein (1971)[1] studied the effects of bromacil and other herbicides on Bdellovibrio bacteriovorus parasitism of a soil pseudomonad. B. bacteriovorus, a small endoparasitic bacterium indigenous to soil, mud and sewage can attack and penetrate other susceptible gram-negative bacteria, causing host lysis and release of parasite progeny into the surrounding environment. Bromacil showed only a slight inhibition against a Bdellovibrio strain and its Pseudomonas species host using disc assay techniques.

Using three types of soil from Puerto Rico, Liu and Cibes-Viade (1972)[2] studied the effects of bromacil and several other herbicides on the respiration of soil microorganisms. At 10 ppm (equivalent to an application of 4 lb AI/acre), most of the herbicides tested including bromacil, inhibited oxygen consumption slightly in Coto clay soil. None of the herbicides inhibited oxygen consumption noticeably in Fraternidad clay at 10 ppm, but at 100 ppm, oxygen uptake was generally inhibited. In San Anton sandy loam, bromacil and most of the other herbicides tested increased oxygen consumption at 10 ppm, and the respiration rate at 100 ppm.

Steyn and Wolff (1969)[3] investigated the influence of bromacil on the nitrifying and respiratory capacities of soil. Sandy loam was treated with an 80% wettable powder formulation of bromacil at the rate of 4 ppm, which is twice the application rate recommended for this type of soil. No statistically significant differences were found in the ammonium and nitrate nitrogen contents, nor in the amounts of carbon dioxide evolved from treated as compared to untreated soils. Those authors noted that according to the literature, nitrification organisms are relatively sensitive to soil-applied chemicals and are therefore useful indicator organisms. They concluded that the use of bromacil in accordance with the specified label directions would have no statistically significant detrimental effect on the soil microflora.

Kutches et al. (1970)[4] studied the effects of bromacil and several other pesticides on the microbial activity of sheep rumen liquor in vitro. Dry matter disappearance, volatile fatty acid production, and alterations in rumen ciliated protozoa numbers were the criteria measured. Relatively high concentrations (500 μg/ml) of bromacil (and of the other pesticides) were tolerated by rumen microorganisms without deleterious effects on rumen function

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1/ Wehr, N., D. Klein, "Herbicide Effects on Bdellovibrio Bacteriovorus Parasitism of a Soil Pseudomonad", Soil Biol. Biochem., 3(2): 143-9 (1971).

2/ Liu, L. C., and H. R. Cibes-Viade, "Effect of Various Herbicides on the Respiration of Soil Microorganisms," J. Agr. Univ. P.R., 56(4): 417-425 (1972).

3/ Steyn, P.L., and S. W. Wolff, "The Influence of 5-Bromo-3-secondary butyl-6-methyluracil on the Nitrifying and Respiratory Capacities of Soil," Phytophylactica, 1:157-160 (1969).

4/ Kutches, A. J., D. C. Church, and F. L. Duryee, "Toxicological Effects of Pesticides on Rumen Function In Vitro," J. Agr. Food Chem., 18(3):430-433 (1970).

as measured by the three aforementioned parameters. The authors concluded that the concentrations of bromacil (and of the other pesticides studied) that might be ingested by ruminents by way of contaminated feedstuffs would have no, or negligible, effects on rumen digestibility or other rumen functions. Pesticide residues that might be found on contaminated feedstuffs would be expected to be much lower than those studied.

The reports reviewed in this subsection indicate that certain soil microorganisms are capable of degrading bromacil, and that bromacil concentrations in the soil that might be expected from its use in accordance with label directions do not appear to effect soil microflora adversely.

No reports were found on the effects of bromacil on the soil microfauna.

Laboratory Studies - Gardiner et al. (1969)[1] synthesized ^{14}C - labeled bromacil for disappearance and metabolism studies. This molecule was labeled in the 2-position so that the ^{14}C - label would be retained by all metabolites in which the uracil ring had not been degraded. In laboratory studies, soil samples were treated with bromacil at a rate equivalent to 20 lb AI/acre. Of the bromacil applied, 25.3% was decomposed to ^{14}C-labeled carbon dioxide in nine weeks.

Zimdahl et al. (1970)[2] investigated the degradation of bromacil and several other herbicides in Chehalis loam soil in the laboratory. Bromacil was added to this soil at the rate of 8 ppm (by weight). The treated soil was stored at two different temperatures, i.e., 13.2 and 31.2°C. The degradation of bromacil followed a first order rate law with no induction period. Evaluation of the rate constants at the two temperatures permitted calculation (from the Arrhenius equation) of an energy of activation of 3.0 kcal/mole for bromacil degradation. Decomposition of bromacil appeared to occur by breakage of the carbon-halogen bond.

Dowler (1969)[3] used a cucumber bioassay test to determine the persistence of soil residues of bromacil and several herbicides. Cucumber plants were grown in steam-sterilized sand to which the herbicides were added at concentrations ranging from 0.001 to 2.187 ppm weight. Concentrations of bromacil as low as 0.001 to 0.027 ppm weight could be detected by this method. This paper provides details of the bioassay method, but not persistence data.

1/ Gardiner, J. A., R. C. Rhodes, J. B. Adams Jr., and E. J. Soboczenski, "Synthesis and Studies with 2-^{14}C-labeled Bromacil and Terbacil," J. Agr. Food Chem., 17(5):980-986 (1969).

2/ Zimdahl, R. L., V. H. Freed, M. L. Montgomery, and W. R. Furtick, "The Degradation on Triazine and Uracil Herbicides in Soil," Weed Res., 10:18-26 (1970).

3/ Dowler, C. C., "A Cucumber Bioassay Test for the Soil Residues of Certain Herbicides," Weed Sci., 17(3):309-310 (1969).

Rhodes et al. (1970)[1] studied the mobility and adsorption of bromacil and several other pesticides on soils in the laboratory. 2-^{14}C-bromacil at concentrations ranging from 1 to 20 ppm was added to four agricultural soils from different locations, selected to represent a variety of soil types. Soil pH ranged from 5.4 to 6.7; organic matter content from 0.7 to 83.5%. The Freundlich isotherm constants were determined, and the mobility of the test compounds was evaluated by preparing radioautograms of soil thin-layer chromatographic plates. In each of the four different soils, bromacil was relatively more mobile than the other four chemicals studied. Bromacil also showed greater lateral diffusion than the less mobile materials.

Haque and Coshow (1971)[2] studied the adsorption of bromacil from aqueous solutions onto mineral surfaces including illite, montmorillonite, silica gel, humic acid, and kaolinite surfaces. Freundlich-type isotherms best represented the adsorption process. The humic acid surface adsorbed considerably more chemical than other surfaces. Montmorillonite and kaolinite showed a concave-type, humic acid a convex-type adsorption. From the adsorption data at two temperatures, the isosteric heats of adsorption in relation to the amount of chemical sorbed were calculated. The results suggested that for most of the surfaces, the adsorption occurs through physical forces. At very low surface coverage, some hydrogen-bond formation was noticed.

Volk (1972)[3] studied the physicochemical aspects of the interactions between bromacil (and several other pesticides) and soil. Cation saturation and time of exposure did not appreciably affect the adsorption of bromacil on montmorillonite. In another test series, an aqueous solution of bromacil (0.1 meq) was titrated with 0.1 N HCl or NaOH. No inflection points were obtained, indicating that bromacil cannot be titrated in an aqueous solution. However, titration in nonaqueous media indicated that it is weakly acidic.

1/ Rhodes, R. C., I. J. Belasco, and H. L. Pease, "Determination of Mobility and Adsorption of Agrichemicals on Soils," J. Agr. Food Chem., 18(3):524-528 (1970).

2/ Haque, R., and W. R. Coshow, "Adsorption of Isocil and Bromacil from Aqueous Solutions onto Some Mineral Surfaces," Environ. Sci. Technol., 5(2):139-141 (1971).

3/ Volk, V. V., "Physico-Chemical Relationships of Soil-Pesticide Interactions," Oreg. State Univ. Environ. Health Sci. Cent. Annu. Progr. Rep., pp. 186-199 (1972).

Residues in Soil/Field Studies - Gardiner et al. (1969) also studied the disappearance of 2-^{14}C-labeled bromacil applied at the rate of 4 lb AI/acre to the surface of a Butlertown silt loam. Sections of 4-in. diameter stainless steel tubes were driven into the ground to isolate undistrubed columns of soil. About 1.5 in. of each cylinder was left protruding above the ground surface. The radiolabeled bromacil was applied to the soil surface and watered into the soil with five separate rinses, which in total were equivalent to about 0.25 in. of rain. The half-life of bromacil was about 5 to 6 months. After 1 year, about 75% of the total radioactivity applied had disappeared. Bromacil constituted about 90% of the remaining residues, indicating that there was little accumulation of unknown metabolites. No 5-bromouracil was formed as a metabolite, though 5-broma-3-sec-butyl-6-hydroxymethyl uracil and a few related minor metabolites have been identified as metabolites of bromacil in soil. Evaluation of thin-layer chromatography radioautograms of soil extracts indicated that one mode of degradation of bromacil proceeds through hydroxylation of the side chain alkyl groups, presumably followed by ring opening and complete metabolism to carbon dioxide, ammonia, and hydrobromic acid.

Tucker and Phillips (1970)[1/] studied the movement and degradation of bromacil (and several other pesticides) in Florida citrus soil which had been treated repeatedly with these herbicides for up to 5 years. Soil samples were obtained from experimental plots and commercial citrus groves from different areas in Florida. Samples were taken at depths up to 18 in. from the middle of tree rows and kept in frozen storage until analyzed. Bromacil content was determined by gas chromatography. From a total amount of 100 lb AI/acre of bromacil applied in Leon Immokalee fine sand over a 5-year period at the rate of 20 lb AI/acre annually, approximately 1.0 lb AI was present in the soil (0- to 18-in. depth) 13 months after the last application. This represents a 99% loss over the 5-year period.

Bromacil residues were found throughout the 18-in. layer of soil. Its movement into the lower soil layers was shown to be a function of the chemical's water solubility, its adsorption on soil colloids, and soil type. Factors affecting soil persistence include microbial degradation, rainfall, and the degree of uptake by plants. Bromacil is quite water soluble, and may be leached into deeper soil layers in sandy soils. The authors concluded that their results "preclude the possibility of any toxicity (phytotoxicity) to citrus trees due to a buildup of bromacil in the soil following repeated applications at recommended rates."

1/ Tucker, D. P., Jr., and R. L. Phillips, Jr., "Movement and Degradation of Herbicides in Florida Citrus Soil," Citrus Ind., 51(3): 11-13 (1970).

Lange et al. (1968)[1] studied residues of bromacil and other herbicides remaining in California soils following use under typical field conditions at six locations. Bromacil, applied at 1 and 4 lb AI/acre, was among the most persistent of 13 herbicides tested. One year after application, both rates were still toxic to barley, milo, sugar beets, alfalfa, tomato, and wheat. Among these plants, alfalfa was most sensitive, followed by wheat and tomato. Phytotoxicity was still evident in the bromacil-treated plots 24 and 30 months after the initial application. Among the 13 herbicides tested, bromacil generally lasted the longest. At every test location, the bromacil plots were visibly obvious. The authors point out that bromacil is a long-term, broad-spectrum soil sterilent, and that it will find little, if any, use as a selective herbicide on annual crops because of its long-lasting residual effects.

The authors do not provide disaggregate information on the properties of the soils in which these studies were conducted. The organic matter content of the soils ranged from 1.3 to 12.6%; sand, from 24 to 60%; silt, from 27 to 56%; and clay, from 9 to 32%. The amount of moisture received was approximately 30 to 45 in.

Tucker and Phillips (1970) do not provide data on rainfall, and neither Lange et al. (1968) nor Tucker and Phillips (1970) provide data on soil temperatures, soil pH, or other parameters that might help to explain their seemingly divergent observations concerning the persistence of bromacil residues.

Weber and Best (1972)[2] studied the activity and movement of bromacil and 12 other soil-applied herbicides as influenced by soil reaction. Broadleaf weeds were more prevalent in neutral (pH 7) than in acid soils (pH 5). The opposite was true for grass weeds. Bromacil was the second

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1/ Lange, A., B. Fischer, W. Humphrey, W. Seyman, and K. Baghott, "Herbicide Residues in California Agricultural Soils," California Agr., pp. 2-4 (August 1968).

2/ Weber, J. B., and J. A. Best, "Activity and Movement of 13 Soil-Applied Herbicides as Influenced by Soil Reaction," Proc. S. Weed Sci. Soc., 25:403-413 (1972).

most active herbicide against broadleaf weeds and was the most active against the grass weeds. Its activity appeared to be unaffected by soil pH. When the relative mobilities of the herbicides were measured by their movement over the soil surface into adjacent untreated areas, bromacil was very mobile. It also was the most persistent of all herbicides studied.

Stecko (1970)[1/] studied the persistence and vertical movement of bromacil in clay and sandy soils in field tests in Sweden. Herbicides were applied to the surface of the test soils at 2.7, 5.3, and 10.7 lb AI/acre. The herbicides were not incorporated into the soil. Soil samples were taken from six different layers ranging from 0 to 9.4 in., and the residual toxicity was determined by bioassay with white mustard and oats. Within 120 days after treatment, bromacil had moved downwards beyond the 9.4-in. level. Bromacil persisted longer in the sandy soil than in the clay soil, and its phytotoxic residues disappeared more rapidly from the upper than from the lower soil layers.

Stecko states that it is difficult to explain why bromacil disappeared more rapidly from the clay than from the sandy soil. He suggests that there may have been differences in the populations of microorganisms in the two soil types. Another explanation might be that during the summer, the microbial activity in the clay soil was inhibited due to drought.

Horowitz (1969)[2/] evaluated the persistence of bromacil and nine other herbicides in soil in the greenhouse, using an oat bioassay test. Bromacil was applied at concentrations ranging from 0.4 to 12.8 ppm weight. Under these conditions, bromacil was rated as "moderately persistent," its residual activity decreased rather slowly. In general, four triazines and bromacil were the most active among the 10 herbicides studied.

1/ Stecko, V., Jr., "Comparison of the Persistence and the Vertical Movement of the Soil-Applied Herbicides Simazine and Bromacil," 10th British Weed Control Conference Proceedings, 1:303-306 (1970).

2/ Horowitz, M., "Evaluation of Herbicide Persistence in Soil," Weed Res., 9(4):314-321 (1969).

The data reviewed in this subsection on the behavior and persistence of bromacil in the soil indicated that it is not strongly adsorbed on soil colloids. Bromacil appears to be more mobile (both laterally and vertically) in the soil than most other herbicides. Bromacil residues in the soil are moderately persistent. Microbial activity as well as nonbiological factors appear to contribute to its degradation in the soil. In one test, the half-life of a 4 lb AI/acre application of bromacil was about 5 to 6 months. When applied at higher rates, the herbicidal activity of bromacil seems to persist for two or more seasons.

Monitoring Studies - None of the published reports from the National Soils Monitoring Program for pesticides include data on reported uses of bromacil, or records of detection of bromacil residues. Reports scanned in this regard include those by Stevens et al. (1970),[1/] Crockett et al, (1970)[2/] and Wiersma et al (1972).[3/]

Since the results of the 1972 National Soils Monitoring Program were not published at the time of review, data from this source is not included.

Residues in Water

A technical data sheet on bromacil (E. I. du Pont de Nemours and Company, Wilmington, Delaware) states that the water solubility of bromacil is 815 ppm at 25°C, and that it is stable in water and aqueous bases.

Davis and Rahn (1970)[4/] investigated the possible contamination of surface water following the use of bromacil for nonselective weed control. Surface runoffs from an industrial site treated with bromacil were collected and analyzed by gas chromatography. Insignificant amounts of bromacil were found in surface water from the bromacil-treated industrial site following heavy rains within 2 to 4 weeks after application. These amounts were far below levels reported to be injurious to animal or plant life.

No additional reports were found on the presence (or absence) of bromacil residues in water, sediment, or other elements of aquatic ecosystems.

1/ Stevens, L. J., C. W. Collier, and D. W. Woodham, "Monitoring Pesticides in Soils from Areas of Regular, Limited, and No Pesticide Use," Pest. Monit. J., 4(3):145-164 (1970).

2/ Crockett, A. B., G. B. Wiersma, H. Tai, W. G. Mitchell, and P. J. Sand, "National Soils Monitoring Program for Pesticide Residues - FY 1970," U.S. Environmental Protection Agency, Techinical Services Division, unpublished manuscript (1970).

3/ Wiersma, G. B., H. Tai, and P. F. Sand, "Pesticide Residue Levels in Soils, FY 1969-National Soils Monitoring Program," Pest. Monit. J., 6(3):194-201 (1972).

4/ Davis, W. A., and E. M. Rahn, "Atrazine, Trifluralin and Bromacil in Surface Water from Selected Agricultural and Industrial Sites," Northeastern Weed Control Conference Proceedings, 24:283 (1970).

Residues in Air

Hill (1971)[1/] reported that the rate of volatilization of bromacil was measured for weeks at 120°F in air circulation oven. Losses were less than 0.1%/week.

Bingeman et al. (1962)[2/] reported that (based on tests at elevated temperatures and with long exposures to sunlight) loss of bromacil from soil by volatilization and photodecomposition is negligible.

Moilanen and Crosby (1974)[3/] investigated the action of sunlight on dilute (1 to 10 ppm) aqueous solutions of bromacil. Even upon prolonged irradiation, only very low yields of the one detectable photoproduct (5-bromo-6-methyluracil) were obtained. The starting material was recovered almost quantitatively. The results indicate that bromacil is very stable toward sunlight and undergoes only N-dealkylation. The slow breakdown of bromacil in sunlight indicates that photodecomposition probably makes only a minor contribution to the environmental disappearance of this herbicide.

No additional reports were found within the time frame allocated for this review on the presence, fate or persistence of bromacil residues in air. The data reviewed indicates that bromacil does not volatilize from treated soil to any appreciable extent and that it is stable to photodecomposition in sunlight.

Effects and Residues in Nontarget Plants

Since bromacil is primarily a broad-spectrum nonselective herbicides, there are no "nontarget" higher plants per se. However, two noteworthy reports were found on "nontarget" higher plants.

Sterret et al. (1972)[4/] studied antagonistic effects between bromacil and another herbicide (picloram) on oats. It was observed that field applications of combinations of picloram and bromacil in pellet form were less effective in controlling broomsedge (Andropogon virginicus), dallisgrass (Paspalum dilatatum), and several panicums (Panicum sp.) than was bromacil alone. Further experiments were conducted on oats in soil in the greenhouse and in nutrient solution in contrclled environment chambers to study this apparent interaction. When oats were grown in soil treated with combinations of picloram (5 or 10 lb AI/acre) and bromacil (10 lb AI/acre), there was less

1/ Hill, G. D., "Characteristics of Herbicides by Chemical Groups. II. Hyvar X Bromacil," California Weed Conference Proceedings, 23:171-174 (1971).

2/ Bingeman, C. W., G. D. Hill, R. W. Varner, and T. A. Weidenfeller, North Central Weed Control Conference Proceedings, 19:42-43 (1962). In: Herbicide Handbook of the Weed Science Society of America, 3rd ed., p. 68 (1974).

3/ Moilanen, K. W., and D. G. Crosby, "The Photodecomposition of Bromacil," Arch. of Environ. Contam. and Toxicol., 2(1):3-8 (1974).

4/ Sterrett, J. P., J. T. Davis, and W. Hurtt, "Antagonistic Effects Between Picloram and Bromacil with Oats," Weed Sci., 20(5):440-444 (1972).

plant injury than in plants treated with bromacil alone. The higher rate of picloram in combination with bromacil resulted in an almost twofold decrease in response as compared to plants treated with bromacil alone. In nutrient culture experiments, it was found that the uptake of ^{14}C-labeled bromacil alone by oats was nearly double that of ^{14}C-bromacil combined with picloram. Thin-layer chromatographic analyses showed that 47% of the radioactivity from bromacil in the oat was intact bromacil, and 70% of the labeled activity from picloram was unaltered picloram. Roots of oats treated with picloram alone or picloram and bromacil in combination were significantly shorter than the roots of untreated plants, or of plants treated with bromacil alone. Reduction of root length by picloram could be responsible for the reduction in adsorption of bromacil.

Hiranpradit and Foy (1973)[1/] found that soil applications of subtoxic levels of bromacil (0.03 to 0.09 ppm) markedly retarded the senescence of corn leaves. Plants treated with bromacil showed increased chlorophyll retention and incorporation. The authors point out that bromacil does not contain a purine ring, yet it exhibited a cytokinin-like effect of retarding leaf senescence.

Bioaccumulation, Biomagnification

There were no reports found on the possible bioaccumulation or biomagnification of bromacil.

Environment Transport Mechanisms

According to Hill (1971), bromacil has relatively low solubility in water (0.08 or 815 ppm) and a K value (Freundlich constant) of 1.5 on a Keyport silt loam. This combination of water solubility and low soil adsorption results in considerable mobility of bromacil in soil profiles.

In a recent review, Helling et al. (1971)[2/] ranked a number of pesticides by their relative mobility in soils by mobility classes from 1 (immobile) to 5 (very mobile). In this scheme, bromacil was placed in Class 4. Of 82 pesticides included in this tabulation, bromacil was among the 14 materials (mostly herbicides) rated most mobile in the soil.

This data, along with those reviewed in the preceding subsections, indicate that bromacil is relatively stable in the soil, subject to leaching and surface transport via runoff, not strongly adsorbed on soil solids, and not subject to significant volatization from treated soil.

1/ Hiranpradit, H., and C. L. Foy, "Retardation of Leaf Senescence in Maize by Subtoxic Levels of Bromacil, Fluometuron, and Atrazine," Botanical Gazette, 134(1):26-31 (1973).

2/ Helling, C. S., P. C. Kearney, and M. Alexander, "Behavior of Pesticides in Soils," Advances in Agronomy, 23:147-240(1971).

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SUBPART II. D. PRODUCTION AND USE

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This section contains data on the registered uses, and on the production, domestic supply, and use patterns of bromacil. The section summarizes rather than interprets scientific data reviewed.

Registered Uses of Bromacil

Federally Registered Uses - Bromacil is a broad-spectrum general herbicide. It controls a wide range of annual and perennial grasses and broadleaf weeds. Annual weeds are controlled at lower rates, perennial weeds (including grasses) and brush at higher rates.

Bromacil is registered and recommended for nonselective weed and brush control on noncropland, and for selective weed control on a few crops.

Commercially available bromacil formulations are discussed below in the subsection on production and domestic supply.

Bromacil is currently registered in the United States for the following major uses:

1. Nonselective weed and brush control on noncropland areas including railroad, highway and pipeline right-of-ways; petrochemical tanks; lumber yards; storage areas; industrial plant sites; and drainage ditches using the following applications, as found on registered use labels:

   a. 2.4 to 4.8 lb AI/acre for the control of annual weeds and grasses;

   b. 5.6 to 9.6 lb AI/acre for the control of perennial weeds and grasses;

   c. 12.0 to 24.0 lb AI/acre for the control of Johnson grass and other hard-to-kill perennial weeds and grasses;

   d. 5.6 to 24.0 lb AI/acre (broadcast treatment) for the control of undesirable woody plants (rate of application dependent upon suspectibility of target brush and soil adsorptivity; higher rates required on adsorptive soils);

   e. 2.0 lb AI in 5 gal. of water for basal (spot) treatment, to be applied at the rate of 1 to 2 fluid ounces/stem, 2 to 4 in. in basal diameter.

2. Selective weed control in crops using the following applications:[1/]

   a. 1.6 to 6.4 lb AI/acre for the control of annual and perennial weeds in citrus plantings (oranges, grapefruit, lemons), to be applied as a band or broadcast treatment beneath and/or between trees, lower rates for the control of annual weeds and on light soils; higher rates against perennial weeds, especially grasses, and on silt and clay loams. Do not plant treated areas to any crop within two years of last treatment.

1/ U.S. Environmental Protection Agency, EPA Compendium of Registered Pesticides, Vol. I (1970).

b. 1.6 to 4.8 lb AI/acre (restricted to Hawaii) for the control of seedling weeds in pineapple, for broadcast application immediately after planting and before the planting material begins to grow. A second application of 1.6 lb AI/acre may be made prior to differentiation, if needed, as a directed interline spray. Do not replant to any crop other than pineapple within two years of last application.

c. 0.6 to 3.2 lb AI/acre (restricted to Puerto Rico) at planting time is recommended on pineapple. Single overall application immediately after planting. Do not replant to any crop other than pineapple within two years of last application.

For further details on these registered uses of bromacil, including necessary use precautions, specific weeds controlled at different rates, retreatment, moisture requirements, type and duration of efficacy, and other directions to users see Table 5, illustrating a commercial label for bromacil 80% wettable powder (Trademark: Hyvar® X).

Registered uses of bromacil on crops (i.e., citrus and pineapple), established tolerances, dosage rates, and use limitations are tabulated in the EPA Compendium of Registered Pesticides. Tolerances established for bromacil residues on raw agricultural commodities are recorded in the Code of Federal Regulations.[1/]

Bromacil is also registered and recommended for use in combination with diuron. Two wettable powder formulations containing different ratios of these two herbicides are commercially available under the trademark "Krovar." These products are registered and used for the same weed control purposes as formulations containing only bromacil.

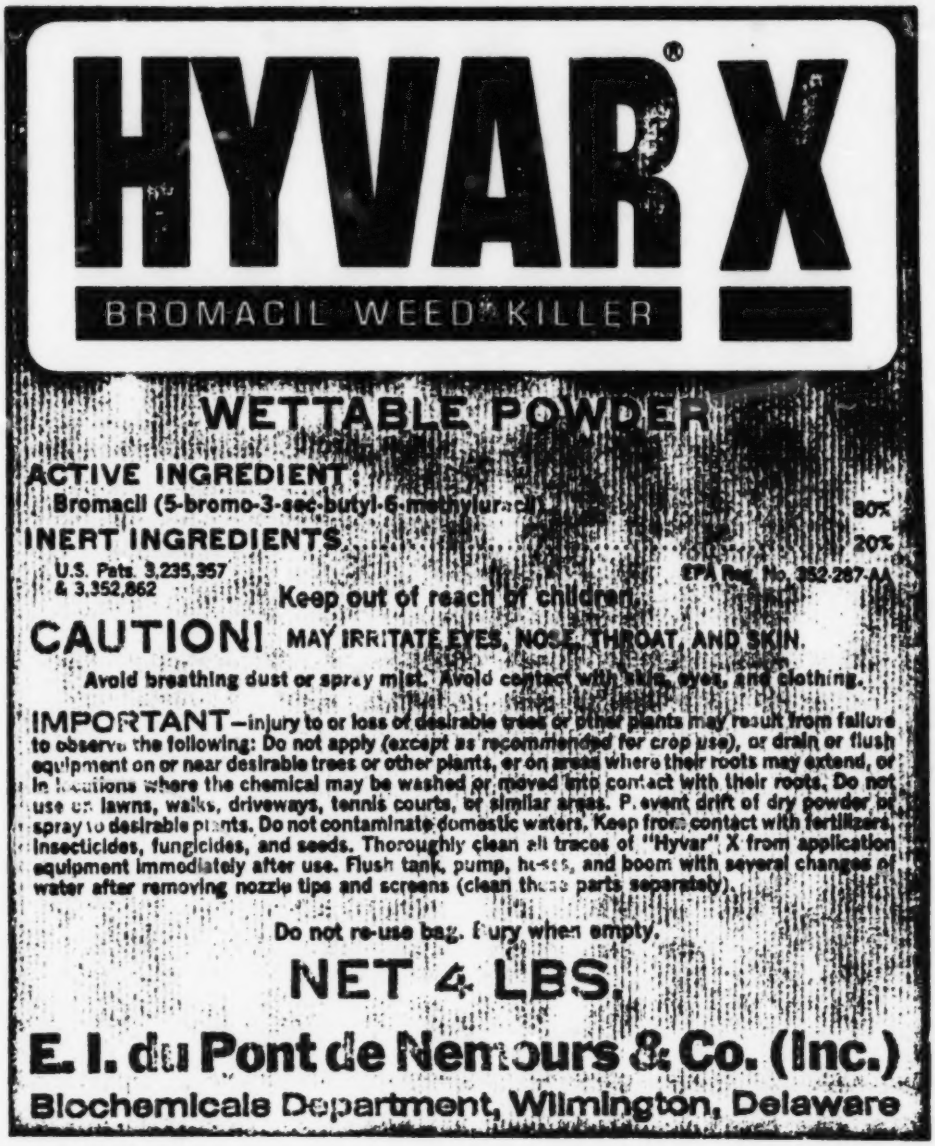
State Regulations - In a number of states, the sale and use of pesticides is subject to state pesticide laws and regulations, in addition to Federal laws and regulations. For instance, in the State of California, 42 specific pesticides have been designated as "injurious or restricted materials." The use of pesticides in this category is subject to special restrictions under regulations administered by the California State Department of Agriculture. Bromacil has not been designated as an "injurious or restricted" pesticide. As far as could be determined, bromacil is not subject to intrastate use restrictions in any state.

Production and Domestic Supply

Volume of Production - According to United States Tariff Commission's 1972 and 1973 final reports[2/] on synthetic organic chemicals, there has been

1/ Code of Federal Regulations, "USDA Summary of Registered Agricultural Pesticide Uses," (Vol. I, 1970), Title 40, Part 180-210, p. 22.
2/ U.S. Tariff Commission, Synthetic Organic Chemicals, U.S. Production and Sales, T. C. Publication 681 (1972, 1973).

Table 5. BROMACIL 80% WETTABLE POWDER (HYVAR® X) LABEL


HYVAR® X
BROMACIL WEED® KILLER
WETTABLE POWDER
ACTIVE INGREDIENT:
Bromacil (5-bromo-3-sec-butyl-6-methyluracil) 80%
INERT INGREDIENTS 20%
U.S. Pats. 3,235,357 & 3,352,862
EPA Reg. No. 352-287-AA
Keep out of reach of children
CAUTION! MAY IRRITATE EYES, NOSE, THROAT, AND SKIN.
Avoid breathing dust or spray mist. Avoid contact with skin, eyes, and clothing.
IMPORTANT—injury to or loss of desirable trees or other plants may result from failure to observe the following: Do not apply (except as recommended for crop use), or drain or flush equipment on or near desirable trees or other plants, or on areas where their roots may extend, or in locations where the chemical may be washed or moved into contact with their roots. Do not use on lawns, walks, driveways, tennis courts, or similar areas. Prevent drift of dry powder or spray to desirable plants. Do not contaminate domestic waters. Keep from contact with fertilizers, insecticides, fungicides, and seeds. Thoroughly clean all traces of "Hyvar" X from application equipment immediately after use. Flush tank, pump, hoses, and boom with several changes of water after removing nozzle tips and screens (clean these parts separately).
Do not re-use bag. Bury when empty.
NET 4 LBS.
E. I. du Pont de Nemours & Co. (Inc.)
Biochemicals Department, Wilmington, Delaware

Source: Label for HYVAR® X bromacil weed killer 80% wettable powder, 4-lb bag, EPA Registration No. 352-287.

Reproduced from best available copy.

Table 5. (Continued)

NON-CROP USE

WEED CONTROL

To control most weeds for an extended period of time on non-cropland areas such as RAILROAD, HIGHWAY and PIPELINE RIGHT OF WAYS, PETROLEUM TANK FARMS, LUMBERYARDS, STORAGE AREAS and INDUSTRIAL PLANT SITES:

Apply 3 to 6 lbs. per acre to control ANNUAL WEEDS and GRASSES such as foxtail, ryegrass, wild oats, crabgrass, cheatgrass, bromegrass, ragweed, lambsquarters, puncturevine and turkey mullein. When applied just prior to or after emergence of annuals, rates as low as 2 lbs. per acre control many annual weeds and grasses in low rainfall areas and give short-term control in higher rainfall areas.

Apply 7 to 12 lbs. per acre to control PERENNIAL WEEDS and GRASSES such as smooth brome, Bahiagrass, bluegrass, redtop, purpletop, quackgrass, broomsedge, aster, dandelion, dog fennel, goldenrod, plantain and wild carrot. In areas with low or seasonal rainfall, rates as low as 5 lbs. per acre control many perennial weeds and grasses.

Apply 15 to 30 lbs. per acre to control JOHNSONGRASS; use at the same rate for OTHER HARD-TO-KILL PERENNIAL WEEDS and GRASSES such as Bermudagrass, Dallisgrass, nutgrass, vaseygrass, saltgrass, bouncingbet, dogbane, bracken fern and horsetail. Where limited rainfall (usually less than 4 inches) occurs during the active growth period, such as some areas of the West, "Hyvar" X usually will not provide satisfactory control of hard-to-kill, deep-rooted perennial weeds such as Johnsongrass.

Note—Use the higher levels of the dosage ranges on adsorptive soils (those high in organic matter or carbon).

Retreatment—Apply 2 to 6 lbs. per acre when annual weeds and grasses reappear on sites where weed growth has been controlled.

For Small Areas—¼ cupful of "Hyvar" X per 250 sq. ft. is approximately 15 lbs. per acre.

BRUSH CONTROL

To control undesirable woody plants on non-cropland areas such as RAILROAD RIGHT-OF-WAYS, STORAGE AREAS, INDUSTRIAL PLANT SITES, and DRAINAGE DITCHES:

Apply in spring or summer as a broadcast or basal (spot) treatment; for use on drainage ditches, apply as a basal (spot) treatment only. **Note:** For effective brush control and prevention of damage to desirable vegetation: do not apply to brush standing in water; do not use water from treated ditches for irrigation; do not use in irrigation ditches nor on right-of-ways or other sites where marketable timber or other desirable trees or shrubs are immediately adjacent to the treated area.

Broadcast Treatment—Apply 7 to 12 lbs. per acre to control oak, willow, sweet gum, and pine; apply 15 to 30 lbs. per acre to control brush such as American elm, winged elm, hackberry, sumac, and cottonwood. Use the higher levels of the dosage ranges on adsorptive soils (those high in organic matter or carbon).

Basal (Spot) Treatment—Mix 2⅔ lbs. in 5 gals. of water and apply at the rate of 1 to 2 fl. oz. per stem 2" to 4" in basal diameter, wet base of stem to run off. Treatment controls woody plants such as cottonwood, hackberry, maple, oak, poplar, red bud, sweet gum, wild cherry, willow, and winged elm.

SELECTIVE USE IN CROPS

"Hyvar" X should be used only in accordance with recommendations on this label, or in separate Du Pont bulletins available through local dealers.

All dosages of "Hyvar" X are expressed as broadcast rates. For band treatment, use proportionately less; for example, use ⅓ of the broadcast rate when band treating ⅓ of the area.

Moisture is necessary to activate the chemical; best results are obtained if moisture is supplied by rainfall or irrigation within two weeks after application.

CITRUS (Oranges, Grapefruit, Lemons)

Apply as a band or broadcast treatment beneath and/or between trees. Avoid contact of foliage and fruit with spray or mist. Temporary yellowing of citrus leaves may occur following treatment.

Because injury to citrus trees may result: do not use on soils low in organic matter (less than 1%) nor on poorly drained soils; do not apply more than 8 lbs. per acre per year; do not treat trees planted in irrigation furrows; do not treat diseased trees such as those with foot rot. Do not use in citrus orchards interplanted with other trees or desirable plants, nor in home citrus plantings or in areas where roots of other valuable plants or trees may extend as plant injury may result. Treated areas may be planted to citrus trees one year after last application; do not replant to other crops within 2 years after last application as plant injury may result.

Trees Established for Four Years or More

Annual Weeds—Including crabgrass, crowfoot, Coloradograss, natalgrass (red top), barnyardgrass (watergrass), sandspur, purslane, Florida pusley, spra yleiop, puncturevine, mustard, lambsquarters, henbit, annual sedge and turkey mullein, apply 2 to 4 lbs. per acre. Apply anytime of the year, preferably shortly before or after weed growth begins when adequate moisture is available.

Perennial Weeds—Best results are obtained if application is made shortly before or shortly after weed growth begins. If dense growth is present, remove tops and spray the ground. Effects on perennial weeds are slow to appear, usually progressing over a period of several months.

Make a single application per year during the period from winter to early summer, use at the following rates:

Soil Type	Lbs. "Hyvar" X Per Acre
Sand, loamy sand	4 to 5
Sandy loam	5 to 6
Silt loam, clay loam	6 to 8

Alternatively, make two applications of 3 to 4 lbs. "Hyvar" X per acre per year. In Florida, Texas, and Louisiana, apply in spring and summer; in California and Arizona, apply in fall and spring.

Table 5. (Continued)

Note—Partial control usually occurs with a single treatment; repeat applications are required to control perennials. "Hyvar" X controls the following:

Bermudagrass	All areas U.S.
Torpedograss, paragrass, pangolagrass, Bahiagrass	Florida
Johnsongrass	Texas
Nutsedge	Texas, California

Control of perennials may be improved by cultivation prior to treatment; otherwise, avoid working the soil as long as weed control continues or else effectiveness of the treatment may be reduced.

Torpedograss Control—Barrier Strip Treatment
For control of torpedograss adjacent to citrus groves to prevent spread of the weed into groves, apply 30 lbs. per acre. Treat a border strip 10 to 20 ft. wide adjacent to the citrus grove, but not closer than 10 ft. to the dripline of citrus trees. Examine treated area every four months after application and spot-treat invading or surviving torpedograss at 30 lbs. per acre (11 oz. per 1000 sq. ft.). For best results apply in late winter or early spring after the torpedograss has broken dormancy and is actively growing. For later season application where growth is rank, mow or disc the area prior to treatment.

PINEAPPLE

Do not replant treated areas to any crop other than pineapple within 2 years after last application as injury to subsequent crops may result.

Hawaii—For control of seedling weeds such as crabgrass, wiregrass, foxtail, chloris, Hisiloa, Flora's paintbrush, balsam apple and Amaranthus, apply 2 to 6 lbs. per acre broadcast immediately after planting and before the planting material begins to grow. Use the lower rates in low rainfall areas (5 to 10 inches annually) and on clean-culture fields; use the higher rates in high rainfall areas (above 10 inches annually) and for trash-mulch fields. An additional application of 2 lbs. per acre may be made prior to differentiation, if needed, as a directed interline spray. Do not spray over top of plants.

Puerto Rico—For control of seedling weeds such as crabgrass, goosegrass, jungle rice, pigweed, and purslane, apply 2 to 4 lbs. per acre broadcast immediately after planting and before planting material begins to grow.

NOTICE TO BUYER

Seller warrants that this product conforms to the chemical description on the label thereof and is reasonably fit for purposes stated on such label only when used in accordance with directions under normal use conditions. This warranty does not extend to use of this product contrary to label use directions, or under abnormal use conditions, or under conditions not reasonably foreseeable to seller; buyer assumes all risk of any such use. Seller makes no other warranties, express or implied.

Made in U.S.A. Printed in U.S.A.

GENERAL INFORMATION

Du Pont "Hyvar" X Bromacil Weed Killer is a wettable powder to be mixed in water and applied as a spray for control of weeds and brush. It is non-corrosive to equipment, non-flammable and non-volatile.

"Hyvar" X is an effective general herbicide for the control of many annual weeds at low rates and perennial weeds and brush at higher rates and is particularly useful for control of perennial grasses. It may be used on non-cropland for non-selective weed and brush control and for selective weed control in certain crops.

Effects are slow to appear and may not become apparent until the chemical has been carried into the root zone of the weeds by moisture. The degree of control and duration of effect will vary with the amount of herbicide applied, soil type, rainfall, and other conditions.

DIRECTIONS

Apply "Hyvar" X as a spray just before or during the period of active growth of plants to be controlled. If dense growth is present, results will be improved if vegetation is removed before treatment. Do not apply when ground is frozen.

Before spraying, calibrate equipment to determine quantity of water necessary to uniformly cover measured area to be treated. Weigh the proper amount of "Hyvar" X and mix into necessary volume of water.

For crop use, apply with a fixed-boom power sprayer properly calibrated to a constant speed and rate of delivery. For calibration instructions, see Du Pont Bulletin, "Instructions for Applying Du Pont Weed Killers for Selective Weed Control in Crops". Use sufficient water (min. 40 gals. per acre) to provide thorough and uniform coverage of the ground. Spray booms must be shut off while starting, turning, slowing or stopping, or injury to the crop or successive crops may result.

For non-crop use, application also may be made with a hand-gun sprayer using at least 200 gals. spray per acre to insure uniform coverage. For small areas, a hand sprayer or sprinkling can may be used.

Nozzle screens should be 50 mesh or larger. Continuous agitation in the spray tank is required to keep the material in suspension. Agitate by mechanical or hydraulic means in the spray tank. If by-pass or return line is used, it should terminate at bottom of tank to minimize foaming. Do not use air agitation.

one major producer of bromacil in the United States, du Pont. The most recent issues of the Farm Chemicals Handbook[1] (1973, 1974) list only du Pont as basic producer of bromacil.

In the Tariff Commission pesticide reports, the production and sale volumes of bromacil are not reported individually. Bromacil is included in a large category "all other cyclic herbicides and plant hormones" which includes, in addition to bromacil, all other cyclic herbicides and plant hormones except maleic hydrazide and the dimethylamine salt of 2,4-D. This group includes such large-volume herbicides as: atrazine and other triazines; 2,4-D acid, esters, and salts; amiben esters and salts; trifluralin; dimethylurea compounds; and many other specified and unspecified herbicides. The reported production volumes for this composite category was 344,789,000 lb AI in 1972 and 357,310,000 lb in 1973.

In comparison to many other herbicides in this category, the production and sales volume of bromacil is so small that it is difficult to make quantitative estimates on bromacil. However, based on studies by Midwest Research Institute and R.V.R. Consultants[2] it is estimated that in 1972, the volume of production of bromacil in the U. S. was approximately 4 million pounds AI.

Imports - Imports of pesticides that are classified as benzenoid chemicals (this group includes bromacil) are reported in a U.S. Tariff Commission annual report.[3]

According to the report there were no imports of bromacil into the United States in 1972.

Exports - Pesticide exports are reported in a Bureau of the Census annual report.

Technical (unformulated) bromacil is cited in the report.[4] In addition to bromacil, a number of other specified synthetic organic herbicide active ingredients are included.

1/ Farm Chemicals Handbook, Meister Publishing Co., Willoughby, Ohio, 1973, 1974.

2/ von Rumker, R., E. W. Lawless, and A. F. Meiners, "Production, Distribution, Use and Environmental Impact Potential of Selected Pesticides," Final Report, Contract No. EQC-311, for Council on Environmental Quality, Washington, D. C. (1974).

3/ U. S. Tariff Commission, Imports of benzenoid Chemicals and Products, T.C. Publication 601, (1973).

4/ U. S. Bureau of the Census, U. S. Exports, Schedule B, Commodity by Country, Section 512.0629, Report FT 410.

Formulations of bromacil are also included.[1/] In addition to several specified bromacil-containing formulations, a number of other formulated herbicides are included.

Total exports of herbicides for 1972 were reported as 34,796,185 lb for technical herbicides and 38,967,237 lb for herbicidal preparations.

The Foreign Trade Division reports indicate that both technical and formulated bromacil are being exported from the United States. However, bromacil exports represent only a small share of the total volume of export of technical and formulated herbicides, respectively. Therefore, the export statistics provide only minimal help in estimating the export volume of bromacil. However, based on information obtained from pesticide trade sources and overseas pesticide markets, it is estimated that the 1972 export volume of bromacil was 0.5 to 1.0 million pounds AI, probably closer to 1.0 million pounds AI.

Domestic Supply - Subtracting estimated exports from estimated total production and assuming no imports, it is estimated that about 3 million pounds of bromacil AI were used domestically in 1972.

A comparable estimate for 1973 cannot be made at this time because all necessary U.S. Tariff Commission and Bureau of the Census Pesticide Reports for 1973 were not available at the time of review.

Formulations - The following bromacil formulations are commercially available in the United States:

1. Hyvar ® X bromacil weed killer, a wettable powder containing 80% bromacil.
2. Hyvar ® X-L bromacil weed killer, a water soluble-liquid containing 2 lb bromacil per gallon (present as lithium salt).
3. Hyvar ® X-P brush killer, pellets containing 10% bromacil.
4. Krovar ® I weed killer, a wettable powder containing 40% bromacil and 40% diuron.
5. Krovar ® II weed killer, a wettable powder containing 53% bromacil and 27% diuron.

In addition, formulators offer combination formulations containing bromacil, including the following:

1. 1.5% bromacil + 66.5% sodium metaborate tetrahydrate + 30.0 % sodium chlorate (Ureabor®), applicable in dry form or as an aqueous spray.

1/ U. S. Bureau of the Census, U. S. Exports, Schedule B. Commodity by Country, Section 599,2080, Report FT 410.

2. 4.0% bromacil + 64.0% sodium metaborate tetrahydrate + 30.0% sodium chlorate (Hibor®), applicable in dry form or as an aqueous spray.

3. 4.0% bromacil + 94.0% sodium metaborate tetrahydrate (Borocil®) applicable in dry form or as an aqueous spray.

Use Patterns of Bromacil in the United States

General - As discussed in the subsection on the registered uses of bromacil in the United States, this product is a broad-spectrum herbicide for nonselective control of many annual and perennial grasses and broadleaf weeds, including brush, on noncropland; and (at lower rates of application) for selective control of annual and parennial weeds in citrus groves, and for the control of seedling weeds in pineapple. Bromacil is primarily an industrial herbicide; agricultural uses comprise only 10 to 15% of its estimated domestic consumption.

The herbicidal potential of bromacil was first recognized and described in the early 1960's. Bromacil has been in commercial use in the United States since the mid-1960's, and its use volume appears to be still on the increase. Data on the uses of bromacil by industrial, commercial and institutional organizations, and by government agencies was obtained by the Midwest Research Institute (von Rumker et al., 1974). In the same project, RvR Consultants obtained information on the farm uses of bromacil from the following sources:

1. Survey of the Federal/State Cooperative Extension Services in all 50 states and in Puerto Rico (conducted in 1973);

2. Analyses of state pesticide use recommendations;

3. Pesticide use reports from the states of Arizona and California;

4. Data on pesticide uses supplied by the EPA Community Pesticide Studies Project in Arizona, Hawaii and Texas;

5. Estimates and information obtained from basic producers of bromacil and other pesticides, and from pesticide trade sources;

6. Agricultural Statistics, an annual publication of the U.S. Department of Agriculture.

Information on the uses of bromacil from all of these sources were utilized in arriving at the estimates summarized in Table 6 and discussed below.

Agricultural Uses of Bromacil - Midwest Research Institute estimates that in 1972 about 400,000 lb of bromacil AI were used for agricultural purposes in the U.S., primarily in the Southwestern states for weed control in citrus groves

Table 6. ESTIMATED USES OF BROMACIL IN THE U.S. BY REGIONS AND CATEGORIES, 1972

Region	Category					
	Agriculture	Industrial/ commercial	Subtotals	Government agencies[g]	Home and garden	Total, all categories
	(Thousands of pounds AI)					
Northeast[a]	--	200	200		--	200
Southeast[b]	40	500	540		--	540
North central[c]	--	400	400		--	400
South central[d]	Neglected	800	800		--	800
Northwest[e]	--	200	200		--	200
Southwest[f]	360	200	560		--	560
Total, all regions	400	2,300	2,700	300	None	3,000

a/ New England States, New York, New Jersey, Pennsylvania.
b/ Maryland, Delaware, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida.
c/ Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas.
d/ Kentucky, Tennessee, Arkansas, Louisiana, Mississippi, Alabama, Oklahoma, Texas.
e/ Montana, Idaho, Wyoming, Colorado, Utah, Washington, Oregon, Alaska.
f/ New Mexico, Nevada, Arizona, California, Hawaii.
g/ No regional breakdown available.
Sources: MRI-RvR estimates. See text.

and in pineapple fields in Hawaii. It is also estimated that a small quantity of bromacil (approximately 40,000 lb) was used on the same crops in the Southeastern states and in Puerto Rico, and an even smaller amount on citrus in Texas.

There were no other major agricultural uses of bromacil in the United States in 1972. However, California data suggests other uses.

Nonagricultural Uses of Bromacil - It is estimated that in 1972 about 2,300,000 lb of bromacil AI were used by industrial and commercial organizations, and about 300,000 lb by government agencies. Bromacil is not registered or recommended for any home garden uses.

In the industrial/commercial weed control sector, the largest quantity of bromacil, about 800,000 lb, was used in the South Central states in 1972; followed by the Southeastern states, 500,000 lb; the North Central states, 400,000 lb; and the Northeastern, Northwestern, and Southwestern states, about 200,000 lb each. This estimated distribution pattern corresponds largely to the length and intensity of weed infestation pressure on noncropland areas as determined primarily be the climate in these regions.

Government agencies, including federal, state, county, and local government units, highway departments, etc., used an estimated 300,000 lb of bromacil in 1972 nationwide. No regional breakdown is available for this estimate.

Thus, considering all domestic uses of bromacil combined (Table 6), Midwest Research Institute estimates indicate that slightly more than 25% of the total quantity used in 1972 was used in the South Central states; about 13% in the North Central states; the balance (less than 10% each) in the Northeastern and Northwestern states.

Bromacil Uses in California - The State keeps detailed records of pesticide uses by crops and commodities. These reports are published quarterly and summarized annually. Table 7 summarizes the uses of bromacil in California by major crops and other uses for the 4-year period 1970 to 1973.

In California, bromacil is not subject to the special restrictions and reporting requirements imposed upon the sale and use of pesticides designated as "injurious or restricted materials." For this reason, the percentage of bromacil use reported to the State Department of Agricul-

Table 7. BROMACIL USES IN CALIFORNIA BY MAJOR CROPS AND OTHER USES, 1970-1973

Crop/use	Year 1973	1972	1971	1970
	(Thousands of pounds AI)			
Citrus	16.3	20.7	16.4	9.4
Other fruit and nut crops[a/]	0.4	0.6	0.3	Neglected
Vegetable and field crops[b/]	0.6	0.4	0.4	None
All other uses[c/]	64.9	131.5	48.0	79.6
Total, all uses	82.2	153.2	65.1	89.0

a/ Includes almonds, avocados, grapes, plums, nectarines, peaches, strawberries (bromacil not registered or recommended for use on any of these crops).

b/ Includes cauliflower, broccoli, melons, corn, cucumbers, lettuce, potatoes, tomatoes, cotton, alfalfa (bromacil not registered or recommended for use on any of these crops).

c/ Includes Federal, state, county and city agencies; the University of California; irrigation, flood control, water resource, and vector control districts or agencies; school districts; residential, structural and turf uses; and uses on industrial and other nonagricultural areas.

Source: California Department of Agriculture, Pesticide Use Reports for 1970, 1971, 1972 and 1973.

ture (and included in its statistics) is probably lower than the percentage for restricted use pesticides. However, the State Department of Agriculture and others familiar with pesticides uses in California believe that the department's statistics do include a high percentage of the actual uses of nonrestricted pesticides, and that these statistics are representative of the use patterns by crops and other uses in California.

According to the California State Pesticide Use Reports (Table 7), the use of bromacil in California for all purposes varied between 65,100 lb in 1971 and 153,200 lb in 1972, with the quantities used in 1970 and 1973 within that range.

The use of bromacil on citrus fruits during this period varied from a low of 9,400 lb in 1970 to a high of 20,700 lb in 1972.

In each of the 4 years covered in Table 7, the largest share of the total bromacil volume used in California (about 75 to 90%) was used by Federal, state, county, and city agencies; irrigation, flood control, water, and vector control districts and agencies; school districts; and for weed control on industrial and other nonagricultural sites.

Tables 8 and 9 present the bromacil uses in California by crops and other uses, number of applications, pounds AI, and numbers of acres treated, for 1972 and 1973, the two most recent years for which data is available. These tables provide a detailed breakdown of the bromacil uses summarized in Table 7 for the years 1972 and 1973.

Table 8. USE OF BROMACIL IN CALIFORNIA IN 1972 BY CROPS AND OTHER USES, APPLICATIONS, QUANTITIES, AND ACRES TREATED

Commodity	Applications[a/]		Lb	Acres
Alfalfa	1		13.33	100.00
Almond	1		117.60	49.00
Avocado	4		411.20	136.00
Cauliflower	1		2.40	6.00
Citron, melon	1		42.90	5.50
Citrus	129		4,185.46	2,628.40
City agency			1,541.15	
Corn--sweet	1		15.10	38.00
County agricultural commissioner			6,222.26	
County or city parks			69.60	
County road			4,827.87	
Crucifer	1	CR	57.60	24.00
Cucumber or pickle	2		6.70	57.00
Federal agency			146.90	
Fallow (open ground)	8		115.82	49.50
Flood control			2,933.30	
Grapefruit	20		408.57	516.00
Grape	3		46.20	43.00
Industrial areas	2		25.60	10.50
Irrigation district			3,347.44	
Lemon	94		5,498.03	2,873.65
Lettuce/head	15		76.50	309.00
Lime	2		14.40	4.50
Nonagricultural areas	132		4,087.49	987.04
Orange	327		10,584.68	7,747.43
Other agencies			93,018.93	
Plum	1		1.60	10.00
Potato	5		64.02	197.00
Reclamation district			52.00	
Residential control			3,546.75	
School district			45.38	
Soil (fumigation only)	1		14.40	1.50
State highway			1,124.40	
Structural control			34.00	
Tangelo	1		16.00	20.00
Tomato	11		122.19	409.00
Turf	2		13.40	5.00
University of California			739.20	
Vector control			1,164.87	
Water areas	46		1,907.80	394.95
Water resources			5,608.08	
Total	809		152,155.92	16,573.97

a/ Only agricultural applications are tabulated in this column.

Source: California Department of Agriculture Pesticide Use Report 1972.

Table 9. USE OF BROMACIL IN CALIFORNIA IN 1973 BY CROPS AND OTHER USES, APPLICATIONS, QUANTITIES, AND ACRES TREATED

Commodity	Applications[a]	Lb	Acres
Alfalfa	8	248.46	390.50
Alfalfa fur seed	1	50.00	40.00
Almond	1	18.00	30.00
Apricot	1	24.00	40.00
Avocado	8	269.00	134.50
Citrus	61	2,455.11	1,915.50
City agency		812.48	
Cotton	1	52.99	300.00
County agricultural commissioner		5,632.10	
County or city parks		20.29	
County road		1,489.80	
Federal agency		176.74	
Fallow (open ground)	5	30.24	20.23
Flood control		3,008.00	
Flowers	3	6.00	30.00
Grapefruit	54	776.05	787.50
Grape	2	34.80	29.00
Industrial areas	8	77.92	39.00
Irrigation district		2,453.74	
Lemon	151	4,106.39	2,577.90
Lettuce/head	2	14.76	45.00
Lime	1	2.00	1.00
Nectarine	3	7.60	24.00
Nonagricultural areas	132	2,155.03	513.09
Nursery stock	1	18.52	1.93
Orange	400	8,921.63	7,463.34
Ornamentals	1 CR	5.83 CR	22.00 C
Ornamental bedding plants	1	1.40	7.00
Other agencies		36,084.84	
Peach	1	31.80	40.00
Potato	2	192.92	182.00
Reclamation district		73.60	
Residential control		4,025.75	
School district		131.09	
Soil (fumigation only)	8	21.21	9.93
Squash, summer	1	0.80	4.00
State highway		1,260.80	
Strawberry	6	32.37	132.00
Structural control		16.80	
Tangerine	1	5.92	4.00
Tomato	7	59.14	155.55
Turf	3	10.79	3.00
University of California		350.40	
Vector control		1,287.71	
Water areas	22	3,738.99	320.25
U-Water areas[b]	1	32.00	0.01
Water resources		1,947.15	
Total	895	82,161.30	15,218.22

a/ Only agricultural applications are tabulated in this column.

b/ U = miscellaneous units.

Source: California Department of Agriculture, Pesticide Use Report 1973.

PART-III. MINIECONOMIC REVIEW

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This section contains a general assessment of the efficacy and cost effectivensss of bromacil. Data on the production of bromacil in the United States as well as an analysis of its use patterns at the regional level and by major application are conducted as part of the Scientific Review (Part II) of this report. The section summarizes rather than interprets scientific data reviewed.

Introduction

The efficacy and cost effectiveness of a specific pesticide should be measurable in terms of the increased yield or improved quality of a treated crop which would result in a greater income or lower cost than would be achieved if the pesticide had not been used. Thus, one should be able to pick an isolated test plot of a selected crop, treat it with a pesticide, and compare its yield with that of a nearby untreated test plot. The difference in yield should be the increase due to the use of the pesticide. The increased income (i.e., the yield multiplied by the selling price of the commodity) less the additional cost (i.e., the pesticide, its application and the harvesting of the increased yield) is the economic benefit due to the use of the pesticide.

Unfortunately, this method has many limitations. The data derived is incomplete and should be looked on with caution. Review of the literature and EPA registration files revealed that experimental tests comparing crops treated with specific pesticides to the same crop without treatment are conducted by many of the state agricultural experimental stations. Only a few of these, however, have attempted to measure increased yield and most of this effort has been directed toward just a few crops such as cotton, potatoes, and sorghum. Most other crop tests measure the amount of reduction in pest levels which cannot be directly related to yield.

Even the test plot yield data are marginally reliable, since these tests are conducted under actual field conditions that may never be duplicated again and are often not representative of actual field use. Thus, yield is affected by rainfall, fertilizer use, severe weather conditions, soil type, region of the country, pesticide infestation levels and the rate, frequency and method of pesticide application.

Because of these factors, yield tests at different locations and in different years will show a wide variance ranging from a yield decline to significant increases. For example, in a year of heavy pest infestation, frequent pesticidal use can result in a high yield increase

because the crop from the untreated test plot is practically destroyed. Conversely, in a year of light infestation, the yield increase will be slight.

The use of market price to estimate the value received by the producer also has its limitations. If the use of the pesticide increases the yield of a crop and the national production is increased, then the market price should decline. According to J. C. Headley and J. N. Lewis (1967),1/ a 1% increase in quantity marketed has at times resulted in a greater than 1% decrease in price. Thus, the marginal revenue from the increased yield would be a better measure of value received.

A third limitation to the quantification of the economic costs and benefits is the limited availability of data on the quantities of the pesticide used by crop or pest, the acres treated, and the number of applications. In most cases the amount of bromacil used on each crop (or noncrop) application is not available.

As a result of these limitations an overall economic benefit by crop or pest cannot be determined. This review presents a range of the potential economic benefits derived from the use of bromacil for control of a specific pest on a specific crop. This economic benefit or loss is measured in dollars per acre for the highest and lowest yield developed from experimental tests conducted by the pesticide producers and the state agricultural experimental stations. The high and low yield increases are multiplied by the price of the crop and reduced by the cost of the bromacil applied to generate the range of economic benefits in dollars per acre.

Economic benefits from noncrop applications (e.g., grass and brush control along highways, utility lines, and railroads) are best measured by an alternative costing method. Alternative methods to chemical control include mechanical control such as mowing, discing, bulldozing and the use of brush cutting machines. Hand labor is often required for mowing around trees, poles and other objects and for weeding or cutting brush. In some cases burning for control of grasses along canal banks is an alternative.

1/ Headley, J. C., and J. N. Lewis, The Pesticide Problem: An Economic Approach to Public Policy, Resources for the Future, Inc., pp. 39-40 (1967).

The true economic benefits cannot be measured because much of the noncrop weed control is for aesthetic reasons such as beautification of highways. It is also a form of preventative maintenance to keep fires from causing damage when grasses are dry. Therefore, the cost of the chemical control should be subtracted from the alternative control cost, such as hand labor or mechanical control, to determine the economic benefit from the use of bromacil.

Bromacil is a broad-spectrum pesticide used as a herbicide and soil sterilant. It controls a wide variety of annual and perennial grasses such as Johnson grass, Bermuda grass, nutsedge and dallisgrass. Brush such as blackjack and post oak, hackberry, maple, oak, poplar, sweet gum, wild cherry and others are also controlled.

Bromacil is a relatively new herbicide having been introduced during the past decade. Although there is a significant number of references relating to the efficacy of bromacil, little is available regarding the economics of its use. This latter situation arises from the difficulty in measuring its true economic value; bromacil often takes two to three years to control vegetation effectively, but the quantity needed to maintain control declines after the initial application.

Most of the bromacil is used to control grass and brush along railroads, utility lines, roads, fences, buildings, and other noncrop areas. It is used for beautification of the area by removal of the weeds, but may be used to prevent fires along railways, or because of federal or state requirements for weed and brush control.

The only registered crop uses are for control of weeds and grasses in pineapple and citrus groves.

The following subsection summarizes available literature on the efficacy and cost effectiveness of bromacil.

Citrus

Bromacil is recommended for control of annual and perennial grasses in citrus groves. Control of grasses can promote faster tree growth by reducing the competition for water. It also improves spraying effectiveness and yields.

Efficacy Against Pest Infestation

Only one reference was found in the literature which relates bromacil use to improved yields. Tucker et al. (1971)[1] initiated experiments in Florida in 1967 to evaluate several soil residual herbicides over a 3-year period. These herbicides were tested on oranges and tangelos.

The results showed that bromacil consistently proved to be the most wide-spectrum herbicide and provided the best control over the 4-month period at all locations. Its "burndown" action was good without a surfactant and its residual control was satisfactory. Bermuda grass was the main grass controlled. Spanish needles, pigweed and Vasey grass became a problem in some of the plots. Control of weeds by bromacil averaged from 75 to 90% in the four counties under test.

Tree growth varied in each county and was usually faster with the bromacil treatment. Tree growth was associated with degree of weed removal and depth of tree feeder roots. Mechanical hoeing severely pruned the feeder roots in some areas limiting growth.

The influence of bromacil on fruit yield and quality was measured in one test. With bromacil applied at a rate of 3.5 lb/acre, the yields compared to a mechanically hoed check increased from 200 boxes/acre to 225 boxes/acre.

Cost Effectiveness of Pest Control

The price of oranges in 1972 averaged $2.42/box (Agricultural Statistics 1973)[2], and the cost of bromacil averaged $9.50/lb of active ingredient (Bost, 1974)[3].

Using the above prices and costs the increased income for the 25-box yield increase would be $60.50/acre. Bromacil costs at an application rate of 3.5 lb/acre would be $33.25. This would result in an economic benefit of $27.25/acre based upon this test.

1/ Tucker, D. P. H., and R. L. Phillips, "Weed Control Demonstrations in Florida Citrus Groves," Southern Weed Science Society Proceedings, 24:235-240 (1971).

2/ United States Department of Agriculture (1973). Agricultural Statistics 1973.

3/ Bost, W. M., Director, Cooperative Extension Service, Mississippi State, Mississippi, personal letter to D. F. Hahlen (1974).

The actual economic benefits for this test would be greater since the yield comparisons were made with a mechanically hoed test plot. A completely untreated field could have produced a much lower yield than the hoed plot.

Noncrop Brush and Weed Control

Efficacy Against Pest Infestation

Bromacil is used for a wide variety of weed and brush control applications by industry, commercial firms and local governments. It is used along railroad right-of-ways, in drainage ditches, around utility poles and lines, on farm fence rows and along embankments. It controls a wide number of grasses and woody plants. Walls (1971)[1/] evaluated bromacil for control of highway weeds in Georgia, North Carolina, and South Carolina, and found that bromacil controlled 100% of the annual weeds and grasses, 60% of perennial weeds, 10% of Bermuda grass and 30% of the nutsedge when applied at a rate of 4 lb/acre. Almost 100% control was achieved when applied with 2,4-D and 2,4,5-T amine and Dowpon C.

Rogers (1967)[2/] tested bromacil for control of brush in drainage ditches in the south and achieved 95% control of willow, cottonwood, and water locust with doses ranging from 7.5 to 15 lb AI/acre. Persimmons, American elm, green ash and hackberry were 95% controlled with 15 to 20 lb AI/acre.

Lewis (1968)[3/] tested several soil sterilants on sand soil in West Florida for control of annual grasses and weeds such as Bahia, spurge, pokeweed, Bermuda grass, vasey grass, nutsedge, crabgrass, and smut grass. He concluded that bromacil had the longest residual action and was most effective at 10 or 20 lb/acre.

1/ Walls, C. E., "Post-Emergence Control of Vegetation in Asphalt Highway Shoulders," Southern Weed Conference Society Proceedings, 24:308-309 (1971).

2/ Rogers, A. G., "Bromacil Effective for Control of Willow and Cottonwood in Drainage Ditches," Southern Weed Science Society Proceedings, 20:218-220 (1967).

3/ Lewis, W. F., "Test of Soil Sterilants in West Florida on Sand Soil," Southern Weed Science Society Proceedings, 22:273-274 (1968).

Peevy (1973)[1] evaluated bromacil and picloram for control of southern hardwoods. Bromacil-treated plots showed a crown reduction after 17 months of 98% for post oak, 93% for blackjack oak, and 89% for hickory when applied at 5 to 10 lb/acre. It was much less effective against huckleberry (16%), American beauty berry (34%) and sassafras (48%). Similar results were achieved by Peevy (1971)[2] for control of blackjack and post oak.

Harris et al. (1971)[3] reported on tests to control woody plants in Ohio, Michigan, Indiana, and Kentucky in 1968. At applications of 7 ounces/stem, 100% root kill was achieved on maple, sweet gum, box elder, wild cherry, oak, sumac, white ash, elm, sassafras, hackberry, red bud, dogwood, poison ivy, winged elm, willow and cottonwood.

Dunn (1967)[4] evaluated sterilants for control of grasses and trees on riprap along Lake Pontchartrain levees in New Orleans. He found bromacil the most suitable herbicide for control of false willow, tallow, Bermuda and Vasey grasses when applied at rates of 12 to 16 lb/acre.

Cost Effectiveness of Pest Control

The economic benefits of the use of bromacil will vary depending upon the system being controlled, the degree of control and the cost of alternate treatment. Data that compared the costs of alternate methods of control is summarized here.

The town of West Springfield, Massachusetts (Chemical Brush Program, 1973)[5] estimated a cost of $300.00 to $400.00/acre for cutting and chopping small trees and dense brush thickets along flood control dykes. A program of chemical control using bromacil cut this figure in half resulting in economic benefits of $150.00 to $ 0.00/acre.

1/ Peevy, F. A., "Bromacil and Picloram Under Southern Upland Hardwoods," Weed Sci., 21:54-56 (1973).

2/ Peevy, F. A., "Application Data and Dosage Influence Kill of Hard woods by Soil Application of Bromacil, Fenuron, and Picloram," Southern Weed Science Society Proceedings, 24:271-273 (1971).

3/ Harris, C. B., Jr., and Turney J. Hernandez, "Basal Stem Soil Applications of Bromacil for Woody Plant Control," Southern Weed Science Society Proceedings, 24:321-322 (1971).

4/ Dunn, C. R., "Riprap Test Work on Lake Pontchartrain Levees," Southern Weed Science Society Proceedings, 20:207-211 (1967).

5/ "Chemical Brush Program Helps Guard a City," Reprinted from Public Works, 104:3 (March 1973).

Offutt (1967)[1/] compared mechanical and chemical weed control methods for the lower Tule River irrigation district. Mechanical control cost $134.00/mile or $34.00/acre. Chemical control costs averaged $324.00/mile the first year but were projected at an average of $110.00/mile or $27.50/acre for future control. This would result in an economic benefit of $6.50/acre, assuming that bromacil use averaged 1 lb/acre/year and application was 2 lb/acre every 2 years or 3 lb/acre every 3 years.

In evaluating the economic benefits of chemical weed control, initial costs are often high, because high dosage rates are usually required for initial applications of bromacil, but subsequent applications for maintenance of the area require significantly less chemical. Therefore, tests should cover at least a 3-year period and projections of future costs to maintain the area should be taken into consideration when evaluating chemical control.

1/ Offutt, J. R., "Chemical Weed Control Replaces Mechanical Weed Control in Ditch Maintenance," California Weed Conference Proceedings, 19:32-37 (1967).

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